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CONDENSATION PROBLEMS IN YOUR HOUSE: PREVENTION AND SOLUTION

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ABSTRACT

Excessive moisture in some form is often the cause of condensation problems in a house or other structure. Perhaps the most aggravating and also the most easily prevented are those caused by the movement of water vapor through walls or ceilings. Such problems may result in excessive maintenance costs, such as the need for frequent repainting and increased heating costs. However, properly installed vapor barriers, in conjunction with proper use of insulation, and adequate ventilation will avoid most of such difficulties.

The results of many years of research by Forest Products Laboratory and other scientists, together with their field experience in

solving condensation problems, have provided much valuable information. This publication contains recommendations based on these data. In addition to good practices in the use of vapor barriers, insulation, and ventilation, other construction details are also described and illustrated. Such practices followed in the construction of a new home can pay for themselves many times over in reduced maintenance costs.

This publication is based on USDA Forest Service Research Paper FPL 132, "Condensation Problems: Their Prevention and Solution," Forest Products Laboratory, Madison, Wis.

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CONDENSATION PROBLEMS IN YOUR HOUSE: PREVENTION AND SOLUTION

By
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INTRODUCTION

Purpose and Scope

This publication is intended to serve as a guide for homeowners—not only as a means of preventing condensation problems, but also to better understand their cause. It contains information and recommendations for correct methods of installing vapor barriers, thermal insulation, and inlet and outlet ventilators in new homes. Methods which can be used to correct moisture problems in existing houses are also included.

The majority of the suggestions and recommendations are applicable to the typical wood-frame house. This publication illustrates use of typical materials and does not imply that other materials of equal quality and arrangement cannot be used successfully. Principles involved and procedures used to minimize the problem are equally applicable to commercial and farm buildings where conditions are similar to those in a home.

Because wood is so important a part of American homes, the research program of the Forest Products Laboratory has long included studies on proper use of wood-based materials. Information here is based on research by Laboratory and other scientists and engineers as well as experiences provided by the building industries and homeowners.

Background

In the colder regions of the United States—notably where the January temperature averages 35° F. or lower—the first signs of spring may include dark stains on house siding and peeling paint. These often indicate a cold

weather condensation problem. The formation of icicles or an ice dam at the cornice of a house after a heavy snowfall indicates another type of moisture problem that requires correction.

Condensation can be described as the change in moisture from a vapor to a liquid. In homes not properly protected, condensation caused by high humidities often results in excessive maintenance costs. Water vapor within the house, when unrestricted, can move through the wall or ceiling during the heating season to some cold surface where it condenses, collecting generally in the form of ice or frost. During warm periods the frost melts. When conditions are severe, the water from melting ice in unvented attics may drip to the ceiling below and cause damage to the interior finish. Moisture can also soak into the roof sheathing or rafters and set up conditions which could lead to decay. In walls, water from melting frost may run out between the siding laps and cause staining or soak into the siding and cause paint blistering and peeling.

Wood and wood-base materials used for sheathing and panel siding may swell from this added moisture and result in bowing, cupping, or buckling. Thermal insulation also becomes wet and provides less resistance to heat loss.

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Efflorescence may occur on brick or stone of an exterior wall because of such condensation.

The cost of heat losses, painting and re-decorating, and excessive maintenance and repair caused by cold weather condensation can be easily reduced or eliminated when proper construction details are used.

Changes in design, materials, and construction methods since the mid-thirties have resulted in houses that are easier to heat and more comfortable, but these changes have accentuated the potential for condensation problems. New types of weatherstripping, storm sash, and sheet material for sheathing in new houses provide tight air-resistant construction which restricts the escape of moisture generated in the house. Newer houses are also generally smaller and have lower ceilings resulting in less atmosphere to hold moisture.

Estimates have been made that a typical family of four converts 3 gallons of water into water vapor per day. Unless excess water vapor is properly removed in some way (ventilation usually), it will either increase the humidity or condense on cold surfaces such as window glass. More serious, however, it can move in or through the construction, often condensing within the wall, roof, or floor cavities. Heating systems equipped with winter air-conditioning systems also increase the humidity.

Most new houses have from 2 to 3-1/2 inches of insulation in the walls and 6 or more inches in the ceilings. Unfortunately, the more efficient the insulation is in retarding heat transfer, the colder the outer surfaces become and unless moisture is restricted from entering the wall or ceiling, the greater the potential for moisture condensation. Moisture migrates toward cold surfaces and will condense or form as frost or ice on these surfaces.

Inexpensive methods of preventing condensation problems are available. They mainly involve the proper use of vapor barriers and good ventilating practices. Naturally it is simpler, more inexpensive, and more effective to employ these during the construction of a house than to add them to existing homes.

FACTORS IN THE CONDENSATION PROBLEM

Condensation will take place anytime the temperature drops below dewpoint (100 percent saturation of the air with water vapor at a given temperature). Commonly, under such conditions some surface accessible to the moisture in the air is cooler than the dewpoint and the moisture condenses on that surface.

Concealed Condensation

During cold weather, visible condensation is usually first noticed on window glass but may also be discovered on cold surfaces of closet and unheated bedroom walls and ceilings. Condensation might also be visible in attic spaces on rafters or roof boards near the cold cornice area (fig. 1) or form as frost. Such condensation or melting frost can result in excessive maintenance, such as the need for re-finishing of window sash and trim, or even decay. Water from melting frost in the attic can also damage ceilings below.

Another area where visible condensation can occur is in crawl spaces under occupied rooms. This area usually differs from those on the interior of the house and in the attic because the source of the moisture is usually from the soil or from warm moisture-laden air which enters through foundation ventilators. Moisture vapor then condenses on the cooler surfaces in the crawl space (fig. 2). Such conditions often occur during warm periods in late spring.

An increase in relative humidity of the inside atmosphere increases the potential for condensation on inside surfaces. For example, when inside temperature is 70° F., surface condensation will occur on a single glass window when outside temperature falls to -10° F. and inside relative humidity is 10 percent. When inside relative humidity is 20 percent, condensation can occur on the single glass when outside temperature only falls to about +7° F. When a storm window is added or insulated glass is used, surface condensation will not occur until the relative humidity has reached 38 percent when the outdoor temperature is -10° F. The above conditions apply only where storm windows are tight and there is good circulation of air on the inside surface of the window. Where drapes or shades restrict circulation of air, storm windows are not tight, or lower temperatures are maintained in such areas as bedrooms, condensation will occur at a higher outside temperature.

Visible Condensation

Condensation in concealed areas, such as wall spaces, often is first noticed by stains on the siding or by paint peeling. Water vapor moving through permeable walls and ceilings is normally responsible for such damage. Water vapor also escapes from houses by constant outleakage through cracks and crevices, around doors and windows, and by ventilation, but this moisture-vapor loss is usually insufficient to eliminate condensation problems.



Figure 1.—Darkened areas on roof boards and rafters in attic area indicate stain that stemmed from condensation. This usually could be prevented by vapor barrier in the ceiling and good attic ventilation.

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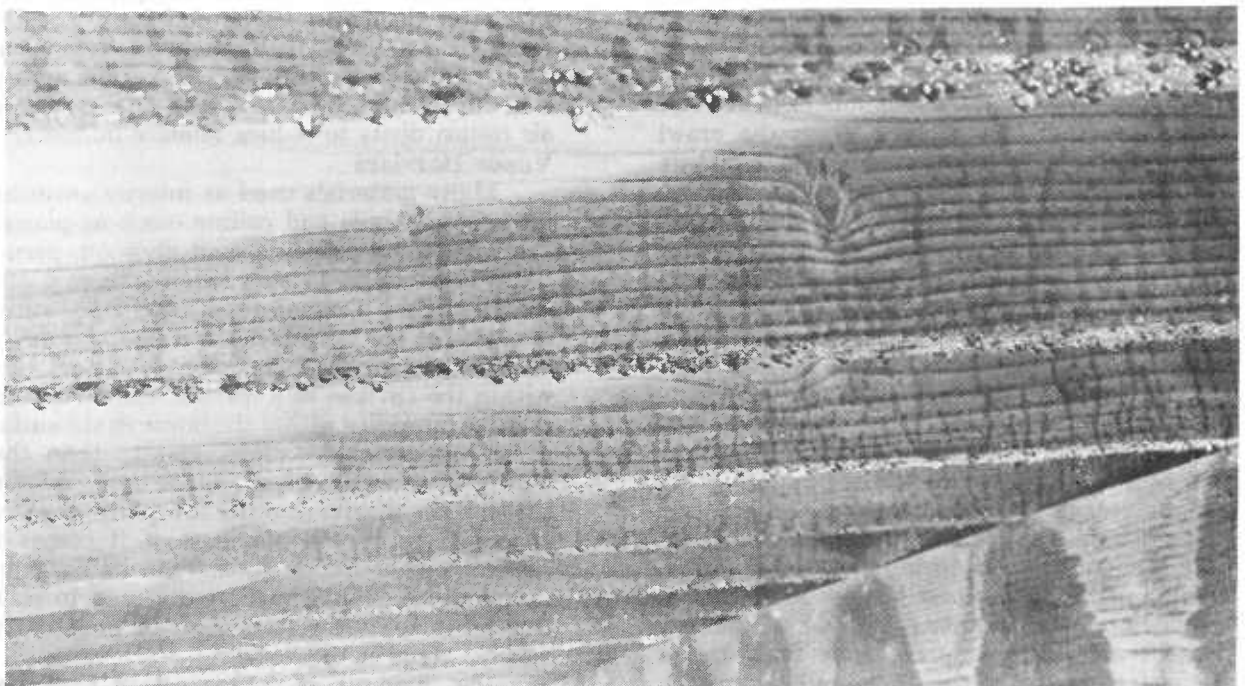


Figure 2.—Surface condensation on floor joists in crawl space. A vapor barrier ground cover can prevent this because it restricts water vapor movement from the soil and thus avoids high humidity of crawl space and subsequent surface condensation.

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Moisture Sources

Interior.—Moisture, which is produced in or which enters a home, changes the relative humidity of the interior atmosphere. Ordinary household functions which generate a good share of the total amount of water vapor include dish-washing, cooking, bathing, and laundry work, to say nothing of human respiration and evaporation from plants. Houses may also be equipped with central winter air conditioners or room humidifiers. Still another source of moisture may be from unvented or poorly vented clothes dryers. Several sources and their effect in adding water vapor to the interior of the house are:

PINTS OF WATER

Plants	- 1.7 for each plant in 24 hours
Showers	- 0.5 for each shower and - 0.1 for each bath
Floor mopping	- 2.9 per 100 square feet, each washing
Kettles and cooking	- 5.5 per day
Clothes (wash- ing, steam ironing, drying)	- 29.4 per week

Crawl space.—Water vapor from the soil of crawl-space houses does not normally affect the occupied areas. However, without good construction practices or proper precautions it can be a factor in causing problems in exterior walls over the area as well as in the crawl space itself. It is another source of moisture that must be considered in providing protection.

Water from construction.—People moving into a newly constructed house in the fall or early winter sometimes experience temporary moisture problems. Surface condensation on windows, damp areas on cold closet walls where air movement is restricted, and even stained siding—all indicate an excessive amount of moisture. Such conditions can often be traced to water used in the construction of a house.

Basement floors, concrete walls, and plastered walls and ceilings require a tremendous amount of water during their construction. While much of this water has evaporated from the surface after a month or so, the addition of heat aids in driving off more moisture as these elements reach moisture equilibrium with the surrounding atmosphere. This moisture creates higher than normal humidities, and the increased amount of vapor drives vapor toward colder areas in attics or in the walls.

A concrete floor in the basement of a small home contains more than 240 gallons of water

when it is poured. The concrete basement walls of this same home contain over 480 gallons of water. If the house is plastered, over 300 gallons of water are used. Thus, it is often a common occurrence to have some moisture problems when a house is just completed. These are normally corrected after the first heating season. However, several methods may be used to reduce this excessive moisture. Perhaps the simplest is to heat and ventilate a new house so that excessive moisture is dissipated outdoors before the occupants move in.

Miscellaneous.—There are other sources of moisture, often unsuspected, which could be the cause of condensation problems. One such source can be a gas-fired furnace. It is desirable to maintain flue-gas temperatures within the recommended limits throughout the appliance, in the flue, the connecting vent, and other areas; otherwise excessive condensation problems can result. If all sources of excessive moisture have been exhausted in determining the reasons for a condensation problem, it is well to have the heating unit examined by a competent heating engineer.

There is a distinct relationship in all homes between indoor relative humidity and outdoor temperature. The humidity is generally high indoors when outdoor temperatures are high and decreases as outdoor temperatures drop. In an exceptionally tight modern house where moisture buildup may be a problem, outside air should be introduced into the cold air return ducts to reduce relative humidity.

Vapor Barriers

Many materials used as interior coverings for exposed walls and ceiling, such as plaster, dry wall, wood paneling, and plywood, permit water vapor to pass slowly through them during cold weather. Temperatures of the sheathing or siding on the outside of the wall are often low enough to cause condensation of water vapor within the cavities of a framed wall. When the relative humidity within the house at the surface of an unprotected wall is greater than that within the wall, water vapor will migrate through the plaster or other finish into the stud space; there it will condense if it comes in contact with surfaces colder than its dewpoint temperature. Vapor barriers are used to resist this movement of water vapor or moisture in various areas of the house.

The amount of condensation that can develop within a wall depends upon (a) the resistance of the intervening materials to vapor transfusion, (b) differences in vapor pressure, and (c) time. Plastered walls or ordinary dry walls have little resistance to vapor movement. However, when the surfaces are painted with

oil-base paint, the resistance is increased. High indoor temperatures and relative humidities result in high indoor vapor pressures. Low outdoor vapor pressures always exist at low temperatures. Thus, a combination of high inside temperatures and humidities and low outside temperatures will normally result in vapor movement into the wall if no vapor barrier is present. Long periods of severe weather will result in condensation problems. Though fewer homes are affected by condensation in mild winter weather, many problems have been reported. Where information is available, it appears that the minimum relative humidities in the affected homes are 35 percent or higher.

Vapor barrier requirements are sometimes satisfied by one of the materials used in a construction. In addition to integral vapor barriers which are a part of many types of insulation, such materials as plastic-faced hardboard and similar interior coverings may have sufficient resistance when the permeability of the exterior construction is not too low. The permeability of the surface to such vapor movement is usually expressed in "perms," which are grains² of water vapor passing through a square foot of material per hour per inch of mercury difference in vapor pressure. A material with a low perm value (1.0 or less) is a barrier, while one with a high perm value (greater than 1.0) is a "breather."

The perm value of the cold side materials should be several times greater than those on the warm side. A ratio of 1 to 5 or greater from inside to outside is sometimes used as a rule of thumb in selecting materials and finish. When this is not possible because of virtually impermeable outside construction (such as built-up roof or resistant exterior wall membranes), research has indicated the need to ventilate the space between the insulation and the outer covering. However, few specific data are available on ventilation requirements for walls.

Areas of vapor barrier use.—Vapor barriers are used in three general areas of the house to minimize condensation or moisture problems:

Walls, ceilings, floors.—Vapor barriers used on the warm side of all exposed walls, ceilings, and floors greatly reduce movement of water vapor to colder surfaces where harmful condensation can occur. For such uses it is good practice to select materials with perm values of 0.25 or less. Such vapor barriers can be a part of the insulation or a separate film. Commonly used materials are (a) asphalt-coated or laminated papers, (b) kraft-backed aluminum foil, and (c) plastic films such as polyethy-

lene, and others. Foil-backed gypsum board and various coatings also serve as vapor barriers. Oil-base or aluminum paints, or similar coatings are often used in houses which did not have other vapor barriers installed during their construction.

Concrete slabs.—Vapor barriers under concrete slabs resist the movement of moisture through the concrete and into living areas. Such vapor barriers should normally have a maximum perm value of 0.50. But the material must also have adequate resistance to the hazards of pouring concrete. Thus, a satisfactory material must be heavy enough to withstand such damage and at the same time have an adequate perm value. Heavy asphalt laminated papers, papers with laminated films, roll roofing, heavy films such as polyethylene, and other materials are commonly used as vapor barriers under slabs.

Crawl space covers.—Vapor barriers in crawl spaces prevent ground moisture from moving up and condensing on wood members, figure 2. A perm value of 1.0 or less is considered satisfactory for such use. Asphalt laminated paper, polyethylene, and similar materials are commonly used. Strength and resistance of crawl space covering to mechanical damage can be lower than that for vapor barriers used under concrete slabs.

Exterior Materials

In new constructions where low permeance vapor barriers are properly installed, most commercially available sheathing and siding materials and coatings can be used without creating condensation problems. However, in structures without vapor barriers, a low permeance material or coating on the outside can retard the escape of moisture which has been forced into the wall from the inside. An alternative finish for such situation is a penetrating stain, which does not form a coating on the wood surface and so does not retard the movement of moisture. Penetrating stains are very durable and easily refinished because they do not fail by blistering or peeling. Where the older home has a paint peeling problem due to condensation, the siding should be painted with white latex paint, which is very porous, and then spot-painted annually wherever peeling occurs. White paint is recommended because it does not fade and retains a good exterior appearance between yearly touchups.

Thermal Insulation

Thermal insulation has a major influence on the need for vapor barriers. The inner face

²438 grains per ounce.

of the wall sheathing in an insulated wall, for example, is colder than the sheathing face in an uninsulated wall and consequently has a greater attraction to moisture. Thus there is greater need for a vapor barrier in an insulated wall than in an uninsulated wall.

Ventilation

Ventilation used in proper amounts and locations is a recognized means of controlling condensation in buildings. Inlet and outlet ventilators in attic spaces, ventilation of rafter spaces in flat roofs and crawl space ventilation aid in preventing accumulation of condensation in these areas. By introducing fresh air into living quarters during the winter, some humid air is forced out of the house while the incoming air has a low water vapor content. Well installed vapor barriers may increase the need for ventilation in living quarters because little of the moisture generated can get out and may build up.

The use of both inlet and outlet ventilators in attic spaces aids in keeping the air moving and preventing the accumulation of frost or condensation on roof boards in cold areas. "Dead" air pockets in the attic can normally be prevented by good distribution of inlet ventilators in the soffit areas. However, there is still a need for vapor barriers in the ceiling; ventilation alone, when insulation is used, does not prevent condensation problems. A good vapor barrier is especially needed under the insulation in a flat roof where ventilation can normally be provided only in the overhang.

Crawl space moisture, which results in high moisture content of the wood members, can be almost entirely eliminated by a vapor barrier over the soil. When such protection is used, the need for ventilation is usually reduced to only 10 percent of that required when a soil cover is not present.

During warm damp periods in early summer, moisture often condenses on basement walls or around the perimeter of the floor in concrete slab houses. Soil temperatures in the northern part of the United States remain quite low until summer, and surface temperatures of the floor or wall are often below dewpoint. When the concrete reaches normal temperature and the atmosphere changes, such problems are normally reduced or eliminated.

GOOD PRACTICE RECOMMENDATIONS

Condensation Zones

The control of condensation through the use of vapor barriers and ventilation should

be practiced regardless of the amount of insulation used. Normally, winter condensation problems occur in those parts of the United States where the average January temperature is 35° F. or lower. Figure 3 illustrates this condensation zone. The northern half of the condensation zone has a lower average winter temperature and, of course, more severe conditions than the southern portion. Areas outside this zone, such as the southeast and west coastal areas and the southern states, seldom have condensation problems. Vapor barriers should be installed at the time of construction in all new houses built within the condensation zone outlined in figure 3 and proper ventilation procedures should be followed. These will insure control over normal condensation problems.

Location of Vapor Barriers

A good general rule to keep in mind when installing vapor barriers in a house is as follows: "Place the vapor barrier as close as possible to the interior or warm surface of all exposed walls, ceilings, and floors." This normally means placing the vapor barrier (separately or as a part of the insulation) on (a) the inside edge of the studs just under the rock lath or dry wall finish, (b) on the under side of the ceiling joists of a one-story house or the second floor ceiling joists of a two-story house, and (c) between the subfloor and finish floor (or just under the sub-floor of a house with an unheated crawl space in addition to the one placed on the ground). The insulation, of course, is normally placed between studs or other frame members on the outside of the vapor barrier. The exception is the insulation used in concrete floor slabs where a barrier is used under the insulation to protect it from ground moisture.

Placement of vapor barriers and insulation in one-story houses are shown in figure 4 (flat roof and concrete floor slab) and figure 5 (pitched roof and crawl space). Figure 6 shows barriers and insulation in a 1-1/2-story house with full basement. Figure 7 depicts a two-story house with full basement. Other combinations of slabs, crawl spaces, and basements in houses with 1, 1-1/2, or 2 stories, should follow the same general recommendations. Detailed descriptions in the use of vapor barriers will be covered in the following sections.

Concrete Slabs

A house constructed over a concrete slab must be protected from soil moisture which may enter the slab. Protection is normally provided by a vapor barrier, which completely isolates the concrete and perimeter insulation

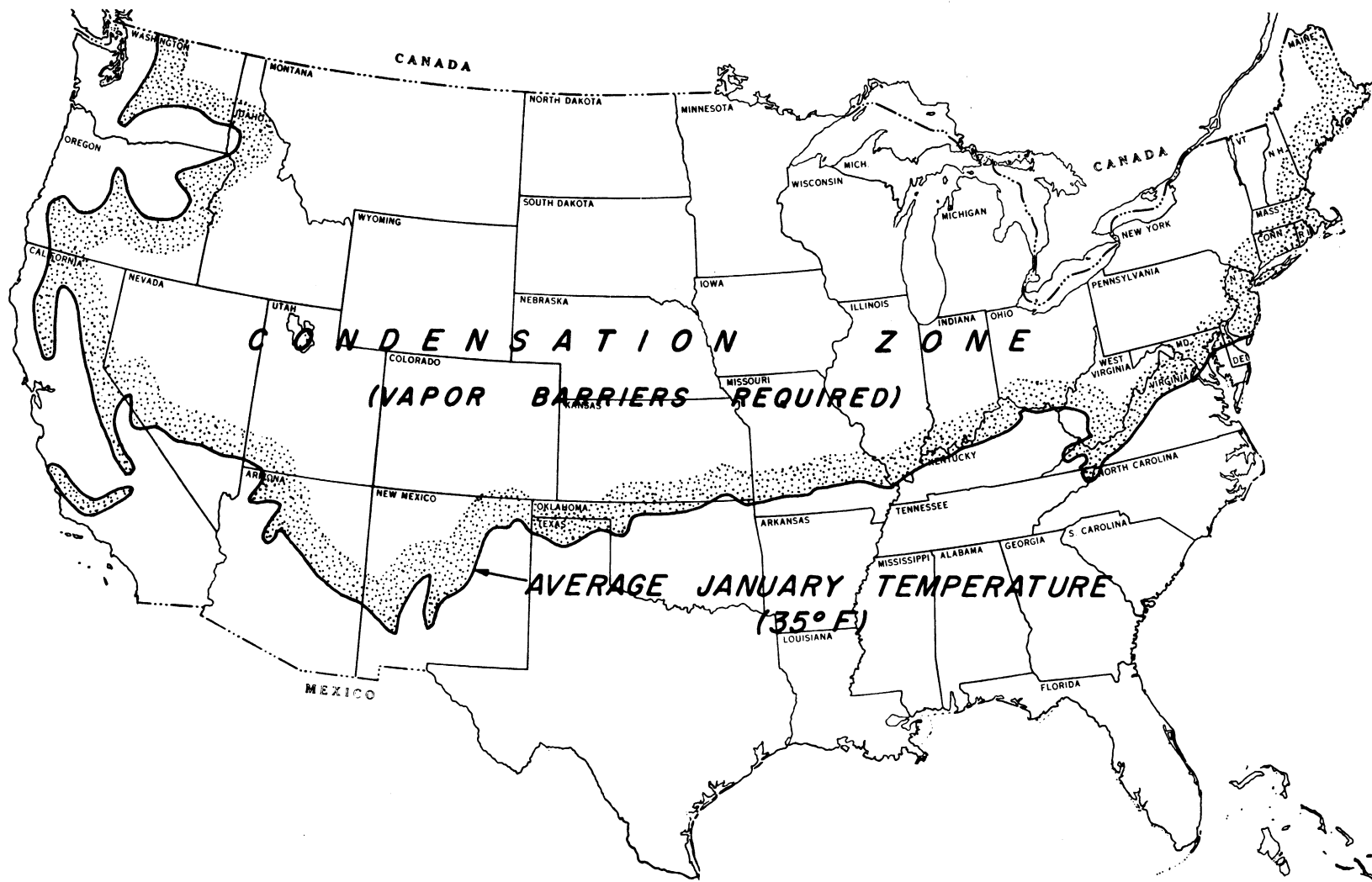


Figure 3.—Winter condensation problems occur where the average temperature for January is 35° F. or lower.

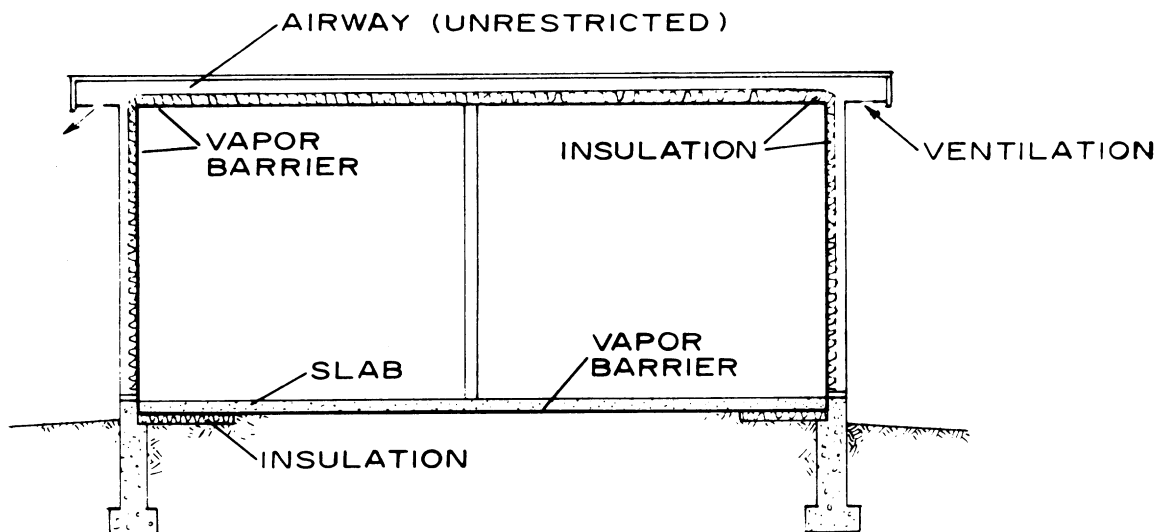


Figure 4.—Location of vapor barriers and insulation in concrete slab and flatdeck roof.

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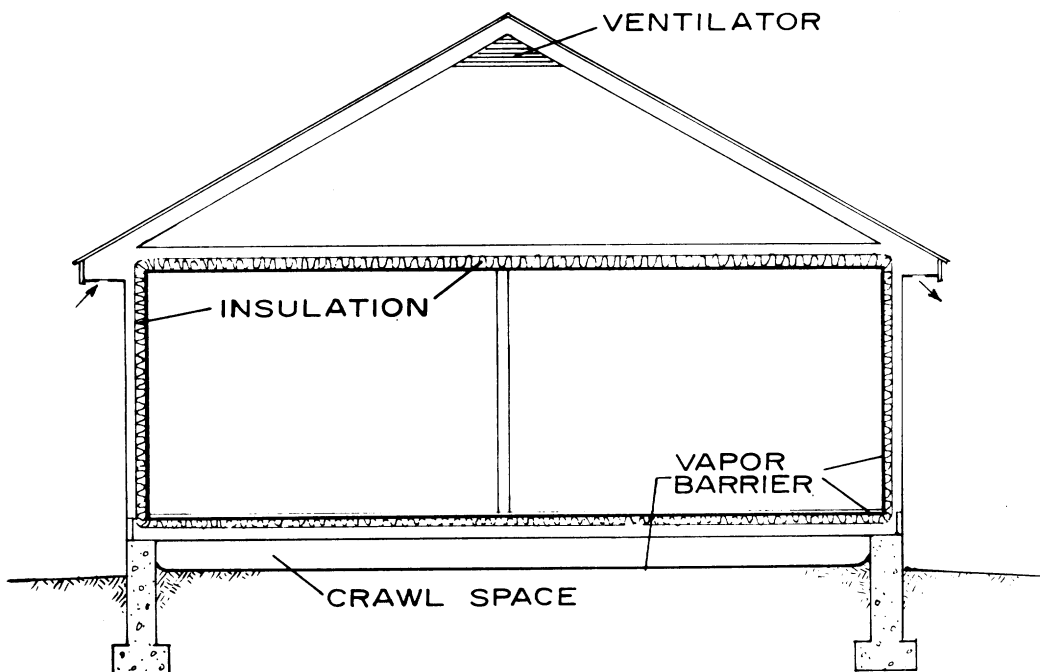


Figure 5.—Location of vapor barriers and insulation in crawl space of another one-story house.

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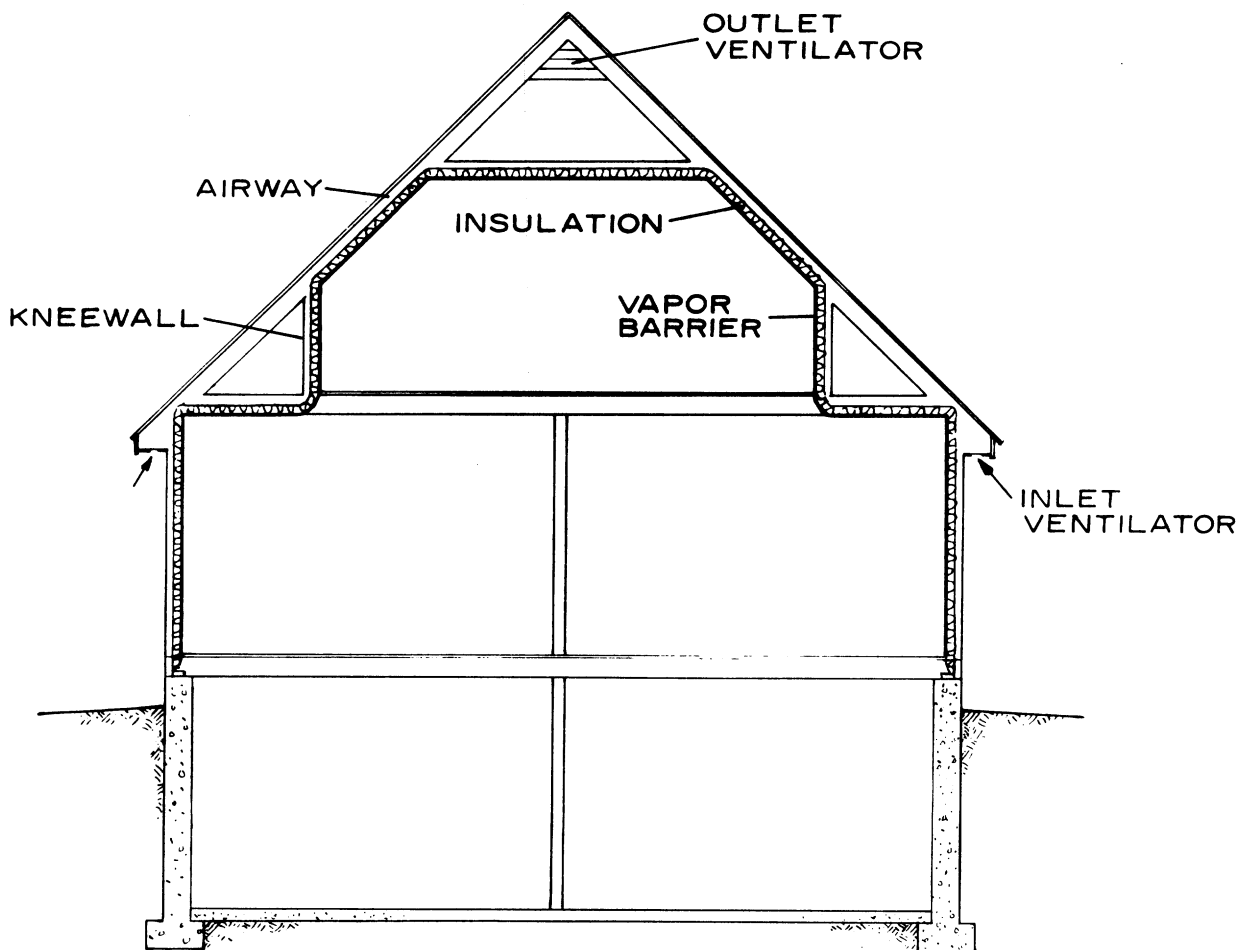


Figure 6.—Location of vapor barriers and insulation in 1-1/2-story house with basement.

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from the soil. Thermal insulation of some type is required around the house perimeter in the colder climates, not only to reduce heat loss but also to minimize condensation on the colder concrete surfaces. Some type of rigid insulation impervious to moisture absorption should be used. Expanded plastic insulation such as polystyrene is commonly used.

One method of installing this insulation is shown in figure 8. Another method consists of placing it vertically along the inside of the foundation wall. Both methods require insulation at the slab notch of the wall. If the insulation is placed vertically, it should extend a minimum of 12 inches below the outside finish grade. In the colder climates a minimum 24-inch width or depth should be used.

In late spring or early summer, periods of high humidity may cause surface condensation on exposed concrete slabs or on coverings

such as resilient tile before the concrete has reached normal temperatures. A fully insulated slab or a wood floor installed over wood furring strips minimizes if not eliminates such problems.

Because the vapor barriers slow the curing process of the concrete, final steel troweling of the surface is somewhat delayed. Do not punch holes through the barrier to hasten the curing process as this will destroy its effectiveness!

Crawl Spaces

Enclosed crawl spaces requires some protection to prevent problems caused by excessive soil moisture. In an unheated crawl space this usually consists of a vapor barrier over the soil, together with foundation ventilators. In heated crawl spaces, a vapor barrier and perimeter insulation is used but foundation ventilators are eliminated.

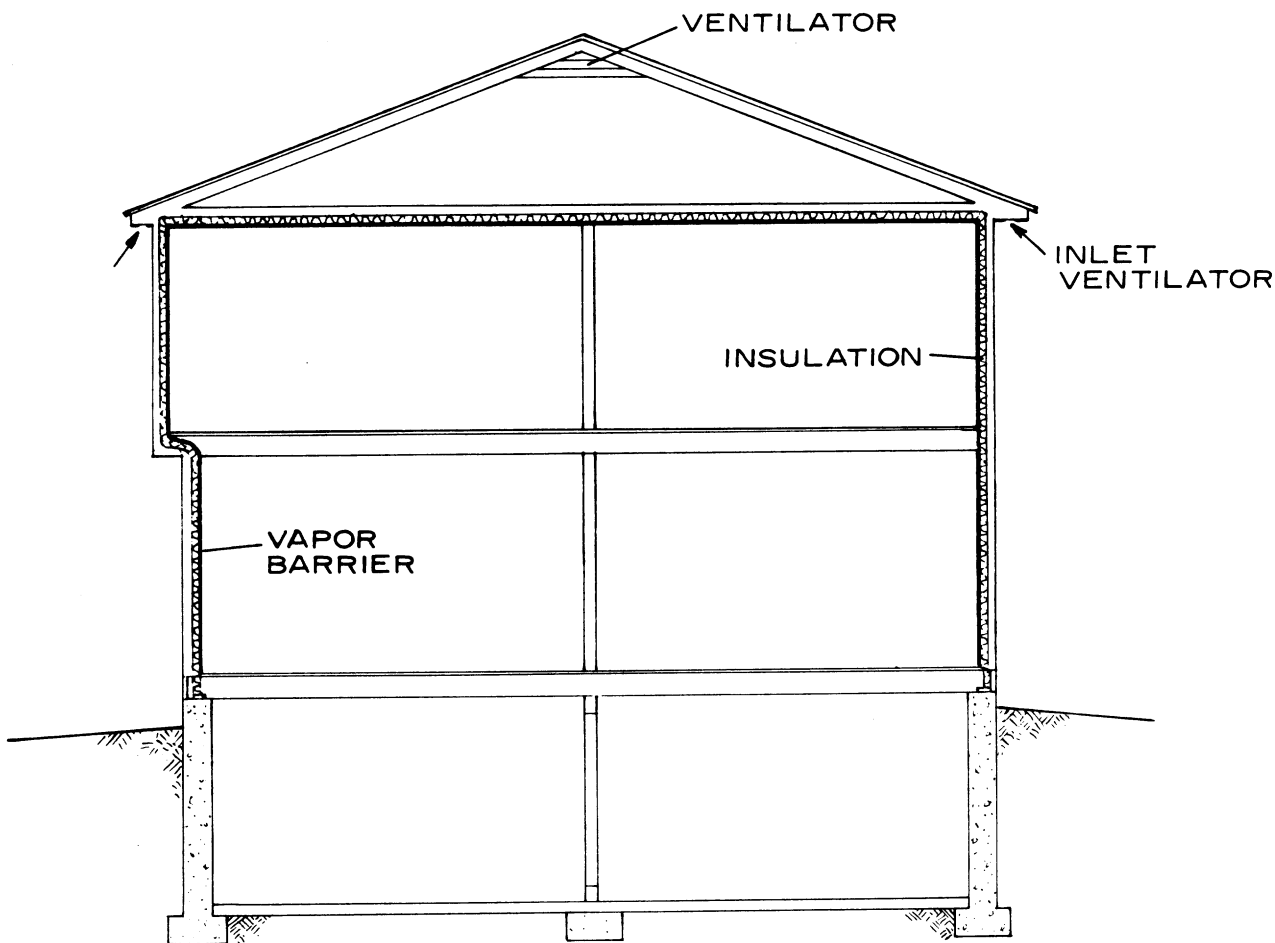


Figure 7.—Location of vapor barriers and insulation in full two-story house with basement.

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Unheated crawl space.—To provide complete protection from condensation problems, the conventional unheated crawl space usually contains (a) foundation ventilators, (b) a ground cover (vapor barrier), and (c) thermal insulation between the floor joists. Foundation ventilators are normally located near the top of the masonry wall. In concrete block foundations, the ventilator is often made in a size to replace a full block, figure 9.

The amount of ventilation required for a crawl space is based on the total area of the house in square feet and the presence of a vapor barrier soil cover. Table 1 lists the recommended minimum net ventilating areas for crawl space with or without vapor barriers.

The flow of air through a ventilator is restricted by the presence of screening and by

the louvers. This reduction varies with the size of the screening or mesh and by the type of louvers used. Louvers are sloped about 45° to shed rain when used in a vertical position. Table 2 outlines the amount by which the total calculated net area of the ventilators must be increased to compensate for screens and thickness of the louvers.

In placing the vapor barrier over the crawl-space soil, adjoining edges should be lapped slightly and ends turned up on the foundation wall (fig. 10). To prevent movement of the barrier, it is good practice to weight down laps and edges with bricks or other small masonry sections.

An unheated crawl space in cold climates offers insufficient protection to supply and disposal pipes during winter months. It is

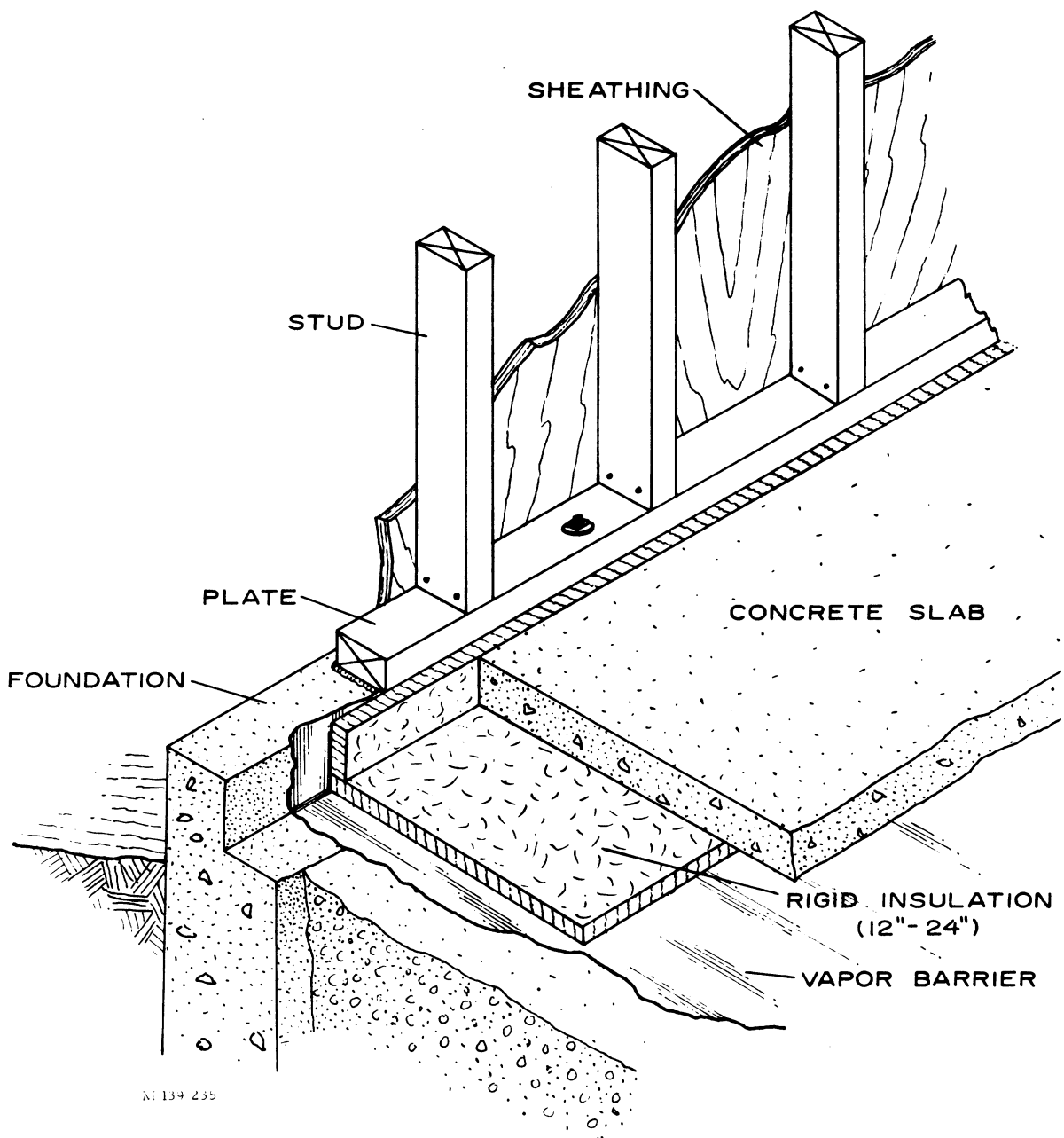


Figure 8.—Installation of vapor barrier under concrete slab.

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common practice to use a large vitrified or similar tile to enclose the water and sewer lines in the crawl space. Insulation is then placed within the tile to the floor level.

Insulating batts, with an attached vapor barrier, are normally located between the floor joists. They can be fastened by placing the tabs over the edge of the joists before the subfloor is installed when the cover (vapor

barrier) is strong enough to support the insulation batt (fig. 10). However, there is often a hazard of the insulation becoming wet before the subfloor is installed and the house enclosed. Thus, it is advisable to use one of the following alternate methods:

Friction-type batt insulation is made to fit tightly between joists and may be installed from the crawl space as shown in figure 11,

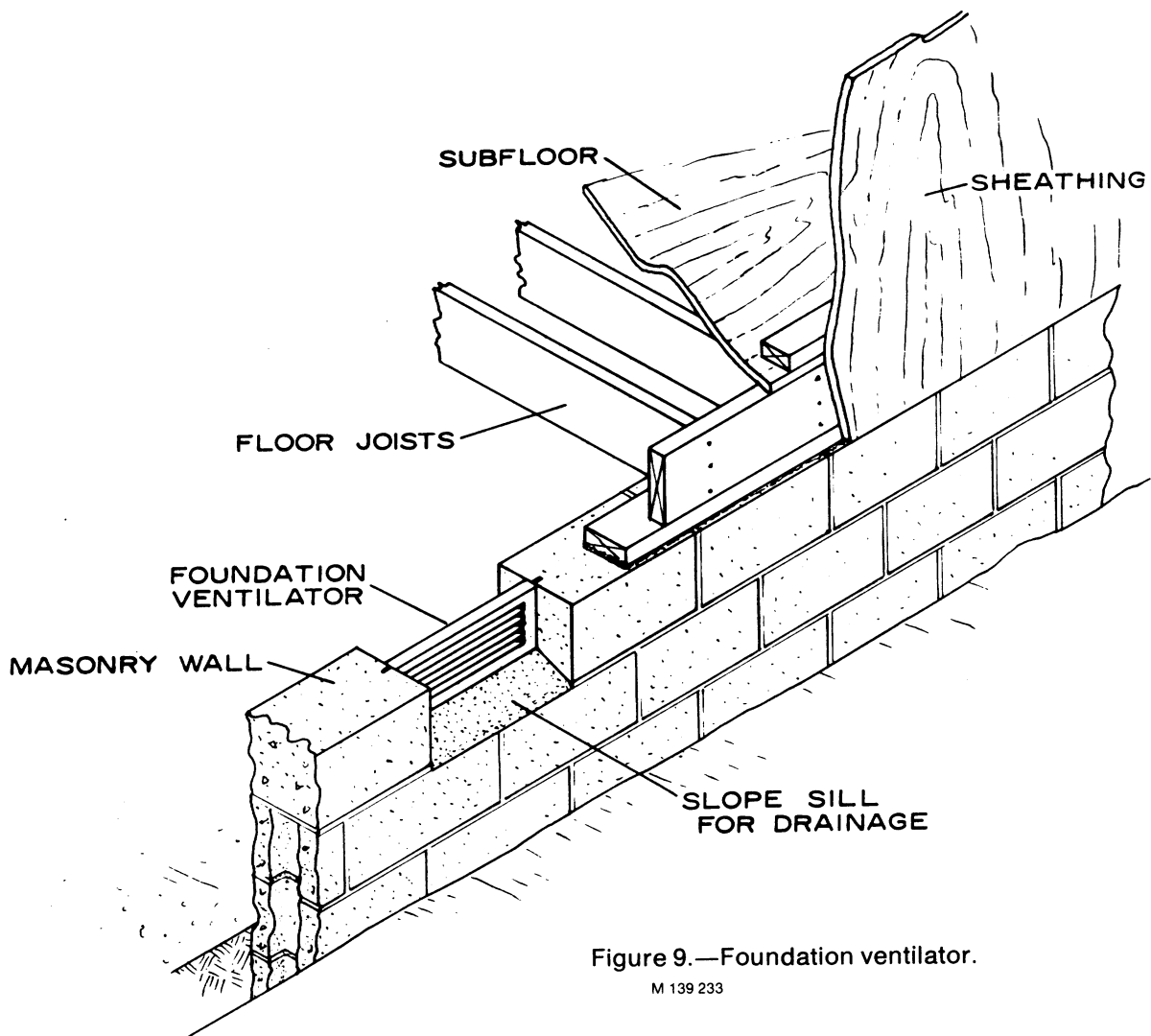


Figure 9.—Foundation ventilator.

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Table 1.—Crawl-space ventilation

Crawl space	Ratio of total net ventilating area to floor area ¹	Minimum number of ventilators ²
Without vapor barrier	1/150	4
With vapor barrier	1/1500	2

¹The actual area of the ventilators depends on the type of louvers and size of screen used—see table 2.

²Foundation ventilators should be distributed around foundation to provide best air movement. When two are used, place one toward the side of prevailing wind and the other on opposite side.

Table 2.—Ventilating area increase required if louvers and screening are used in crawl spaces and attics

Obstructions in ventilators— louvers and screens ¹	To determine total area of ventilators, multiply required net area in square feet by: ²
1/4-inch-mesh hardware cloth	1
1/8-inch-mesh screen	1-1/4
No. 16-mesh insect screen (with or without plain metal louvers)	2
Wood louvers and 1/4-inch- mesh hardware cloth ³	2
Wood louvers and 1/8-inch- mesh screen ³	2-1/4
Wood louvers and No. 16-mesh insect screen ³	3

¹In crawl-space ventilators, screen openings should not be larger than 1/4 inch; in attic spaces no larger than 1/8 inch.

²Net area for attics determined by ratios in figures 22, 23, and 24.

³If metal louvers have drip edges that reduce the opening, use same ratio as shown for wood louvers.

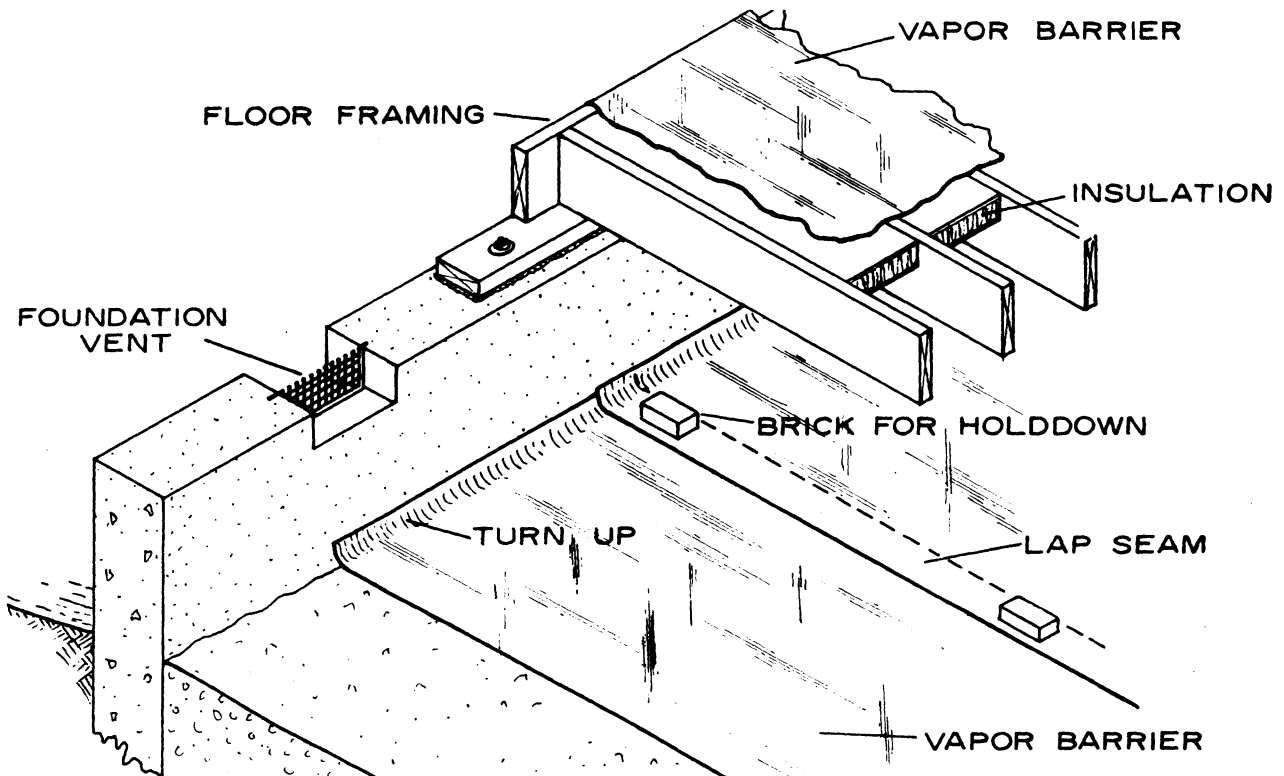


Figure 10.—Vapor barrier for crawl space (ground cover).

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A. It is good practice to use small "dabs" of mastic adhesive to insure that it remains in place against the subfloor. When the vapor barrier is not a part of the insulation, a separate film should be placed between the subfloor and the finish floor.

When standard batt or blanket insulation containing an integral vapor barrier is not installed from above before the subfloor is applied, several alternate methods can be used. If the vapor barrier and enclosing paper wrap is strong enough it can be installed with

a mastic adhesive in the same manner as the friction type (fig. 11, A). Floor insulation may also be supported by a wire mesh held in place by wood strips (fig. 11, B). A third method used to install the insulation from the crawl space consists of using small wood strips applied across the joist space (fig. 11, C). The strips are cut slightly longer than the width of the space and sprung in place so that they bear against the bottom of the insulation.

When only a small amount of insulation is required between the joists because of mod-

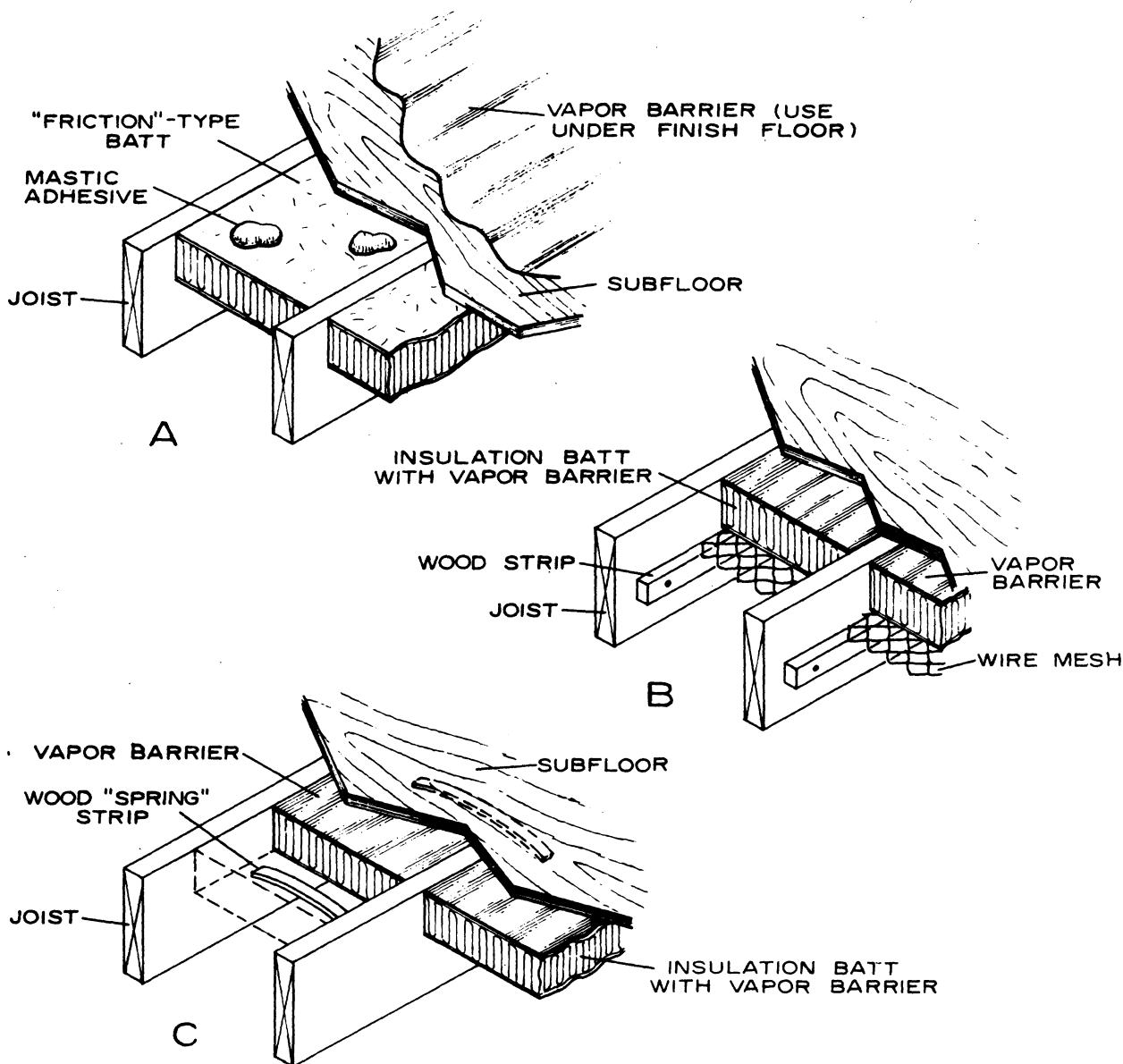


Figure 11.—Installation of vapor barriers and insulation in floor (unheated crawl space): A, Friction-type batts; B, wire mesh support; C, wood strip support.

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erate climates, several other insulating materials can be used. One such material is reflective insulation which usually consists of a kraft paper with aluminum foil on each face. The reflective face must be placed at least $\frac{3}{4}$ inch away from the underside of the subfloor or other facing to be fully effective (fig. 12, A). Multiple or expanded reflective insulation might also be used. A thin blanket insulation can also be used between the joists as shown in figure 12, B. This is installed in much the same manner as thicker insulations shown in

figure 10 or 11. When vapor barriers are a part of the flexible insulation and properly installed, no additional vapor barrier is ordinarily required.

Heated crawl space.—One method of heating which is sometimes used for crawl space houses, utilizes the crawl space as a plenum chamber. Warm air is forced into the crawl space, which is somewhat shallower than those normally used without heat, and through wall-floor registers, around the outer walls, into the rooms above. When such a system is used,

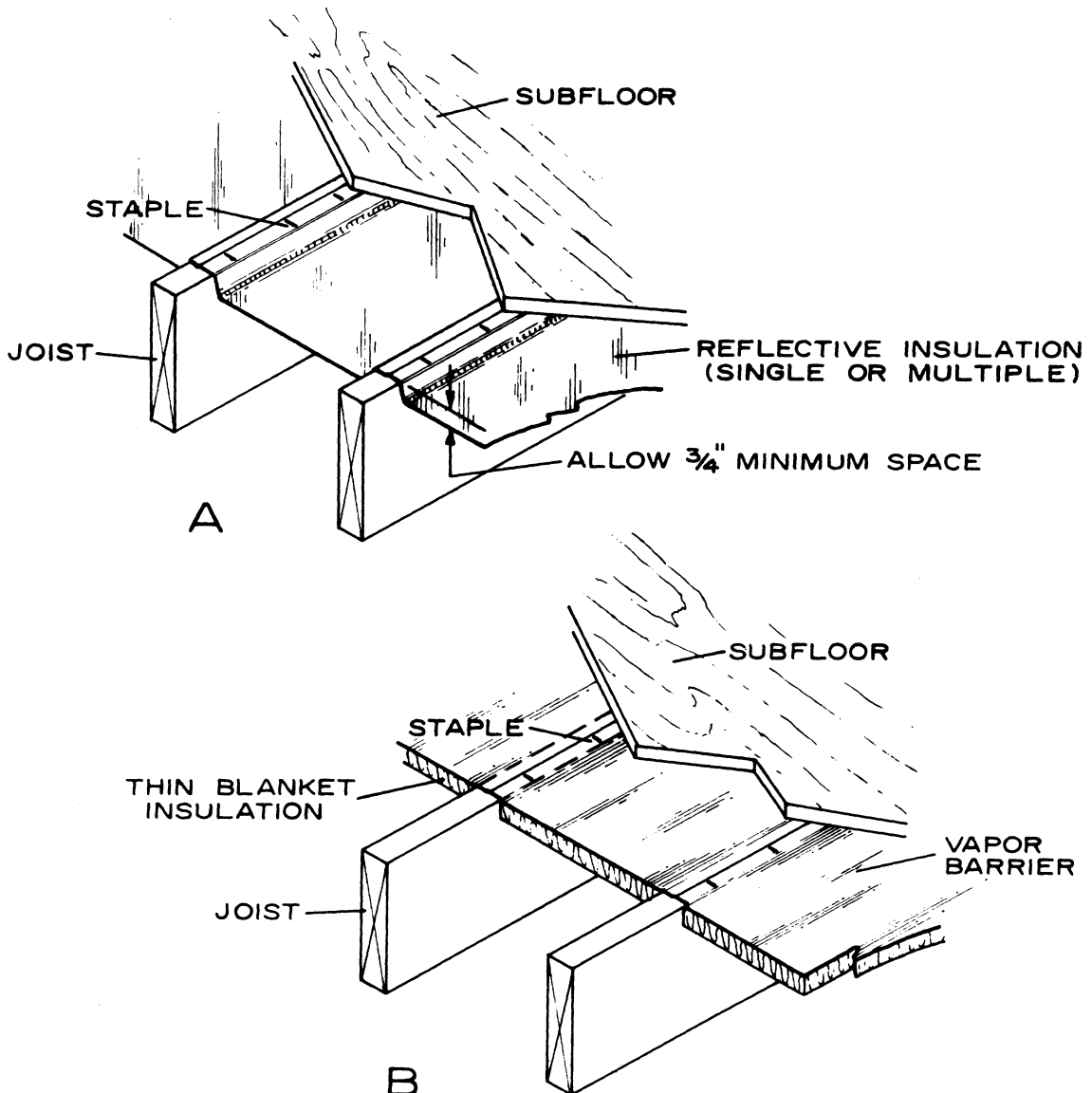


Figure 12.—Installation of vapor barriers and insulation over crawl space: A, Reflective insulation; and B, thin blanket insulation.

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insulation is placed along the perimeter walls as shown in figure 13. Flexible insulation, with the vapor barrier facing the interior, is used between joists; at the top of the foundation wall. A rigid insulation such as expanded polystyrene is placed along the inside of the wall, extending below the groundline to reduce heat loss. Insulation may be held in place with an approved mastic adhesive. To protect the insulation from moisture and to prevent moisture entry into the crawl space from the soil, a vapor barrier is used over the insulation below the groundline, figure 13. Seams of the ground cover should be lapped and held in place with bricks or other bits of masonry. Some builders pour a thin concrete slab over the vapor barrier. The crawl space of such construction is seldom ventilated.

In crawl space houses, as well as other types, the finish grade outside the house should be sloped to drain water away from the foundation wall.

Finished Basement Rooms

Finished rooms in basement areas with fully or partly exposed walls should be treated much the same as a framed wall with respect to the use of vapor barriers and insulation (fig. 14) When a full masonry wall is involved, several factors should be considered: (a) When drainage in the area is poor and soil is wet, drain tile should be installed on the outside of the footing for removing excess water; (b) in addition to an exterior wall coating, a waterproof coating should also be applied to the interior surface of the masonry to insure a

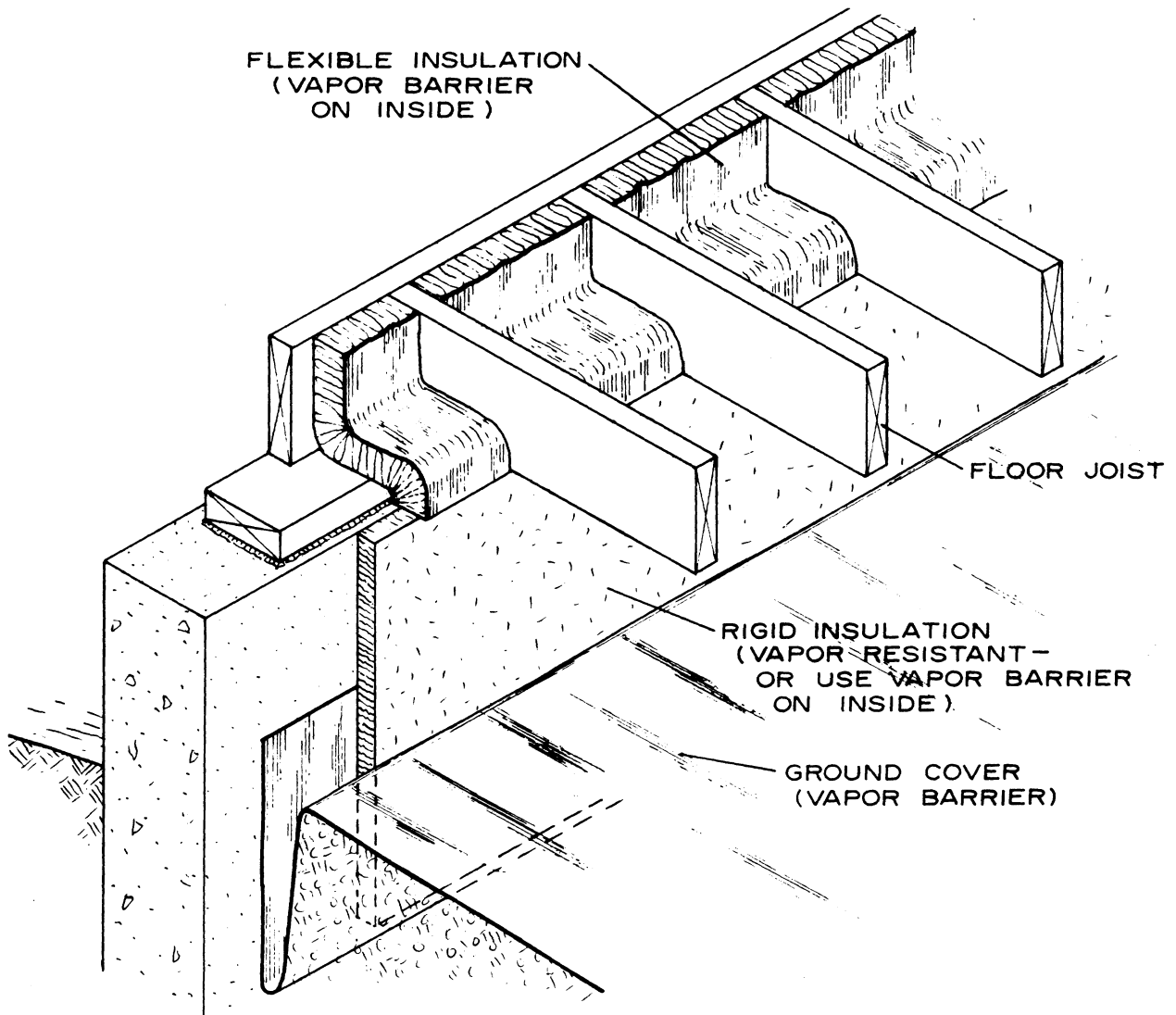


Figure 13.—Installation of vapor barrier and insulation in heated crawl space.

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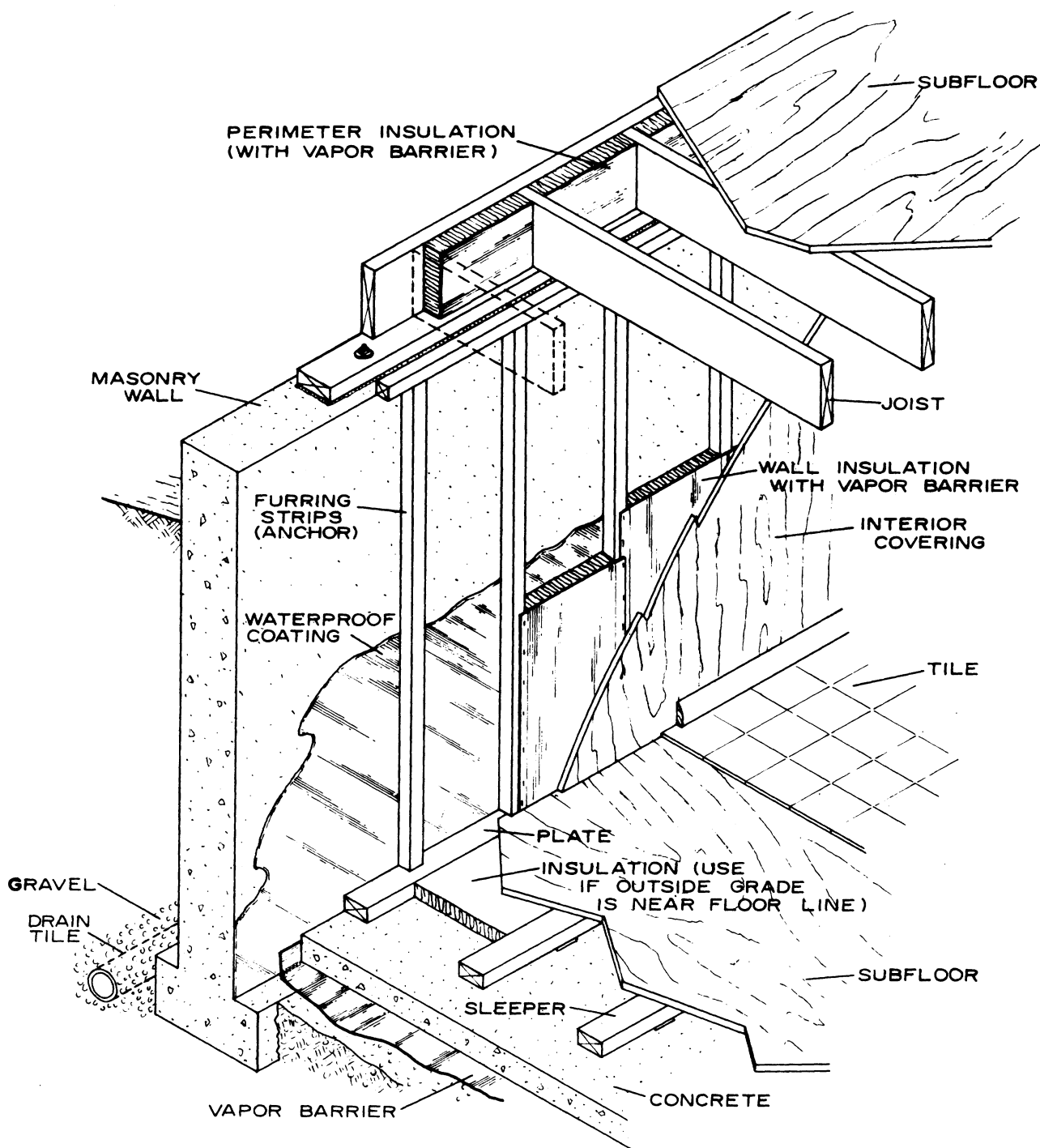


Figure 14.—Installing vapor barrier in floor and wall of finished basement.

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dry wall; and (c) a vapor barrier should be used under the concrete floor slab to protect untreated wood sleepers or other materials from becoming wet.

Furring strips (2- by 2- or 2- by 3-inch

members) used on the wall provide (a) space for the blanket insulation with the attached vapor barrier and (b) nailing surfaces for interior finish, figure 14. One- or 1-1/2-inch thicknesses of friction-type insulation with a vapor barrier

of plastic film such as 4-mil polyethylene or other materials might also be used for the walls.

Other materials which are used over masonry walls consist of rigid insulation such as expanded polystyrene. These are installed with a thin slurry of cement mortar and the wall completed with a plaster finish. The expanded plastic insulations normally have moderate resistance to vapor movement and require no other vapor barrier.

When a vapor barrier has not been used under the concrete slab, it is good practice to place some type over the slab itself before applying the sleepers. One such system for unprotected in-place slabs involves the use of treated 1- by 4-inch sleepers fastened to the slab with a mastic. This is followed by the vapor barrier and further by second sets of 1- by 4-inch sleepers placed over and nailed to the first set. Subfloor and finish floor are then applied over the sleepers.

When the outside finish grade is near the level of the basement floor, it is usually good practice to use perimeter insulation around the exposed edges (fig. 14).

To prevent heat loss and minimize escape of water vapor, blanket or batt insulation with attached vapor barriers should be used around the perimeter of the floor framing above the foundation wall (fig. 14). Place the insulation between the joists or along stringer joists with the vapor barrier facing the basement side. The vapor barrier should fit tightly against the joists and subfloor.

Walls

Blanket insulation.—Flexible insulation in blanket or batt form is normally manufactured with a vapor barrier. These vapor barriers contain tabs at each side, which are stapled to the frame members. To minimize vapor loss and possible condensation problems, the best method of attaching consists of stapling the tabs over the edge of the studs (fig. 15). However, many contractors do not follow this procedure because it is more difficult and may cause some problems in nailing of the rock lath or dry wall to the studs. Consequently, in many cases, the tabs are fastened to the inner faces of the studs. This usually results in some openings along the edge of the vapor barrier and, of course, a chance for vapor to escape and cause problems. When insulation is placed in this manner, it is well to use a vapor barrier over the entire wall. This method is described in the next section.

Another factor in the use of flexible insulation having an integral vapor barrier is the protection required around window and door openings. Where the vapor barrier on the

insulation does not cover doubled studs and header areas, additional vapor barrier materials should be used for protection (fig. 15). Most well-informed contractors include such details in the application of their insulation.

At junctions of interior partitions with exterior walls, care should be taken to cover this intersection with some type of vapor barrier. For best protection, insulating the space between the doubled exterior wall studs and the application of a vapor barrier should be done before the corner post is assembled (fig. 15). However, the vapor barrier should at least cover the stud intersections at each side of the partition wall.

Friction-type insulation.—Some of the newer insulation forms, such as the friction-type without covers, have resulted in the development of a new process of installing insulation and vapor barriers so as to practically eliminate condensation problems in the walls. An unfaced friction-type insulation batt is ordinarily supplied without a vapor barrier, is semi-rigid, and made to fit tightly between frame members spaced 16 or 24 inches on center. "Enveloping" is a process of installing a vapor barrier over the entire wall (fig. 16). This type vapor barrier often consists of 4-mil or thicker polyethylene or similar material used in 8-foot-wide rolls. After insulation has been placed, rough wiring or duct work finished, and window frames installed, the vapor barrier is placed over the entire wall, stapling when necessary to hold it in place. Window and door headers, top and bottom plates, and other framing are completely covered (fig. 16). After rock lath plaster base or dry-wall finish is installed, the vapor barrier can be trimmed around window openings.

Reflective insulations.—Reflective insulations ordinarily consist of either a kraft sheet faced on two sides with aluminum foil, figure 17, A, or the multiple-reflective "accordion" type, figure 17, B. Both are made to use between studs or joists. To be effective, it is important in using such insulation that there is at least a 3/4-inch space between the reflective surface and the wall, floor, or ceiling surface. When a reflective insulation is used, it is good practice to use a vapor barrier over the studs or joists. The barrier should be placed over the frame members just under the dry wall or plaster base (fig. 17, A). Gypsum board commonly used as a dry wall finish can be obtained with an aluminum foil on the inside face which serves as a vapor barrier. When such material is used, the need for a separate vapor barrier is eliminated.

Two-story house.—One of the areas of a

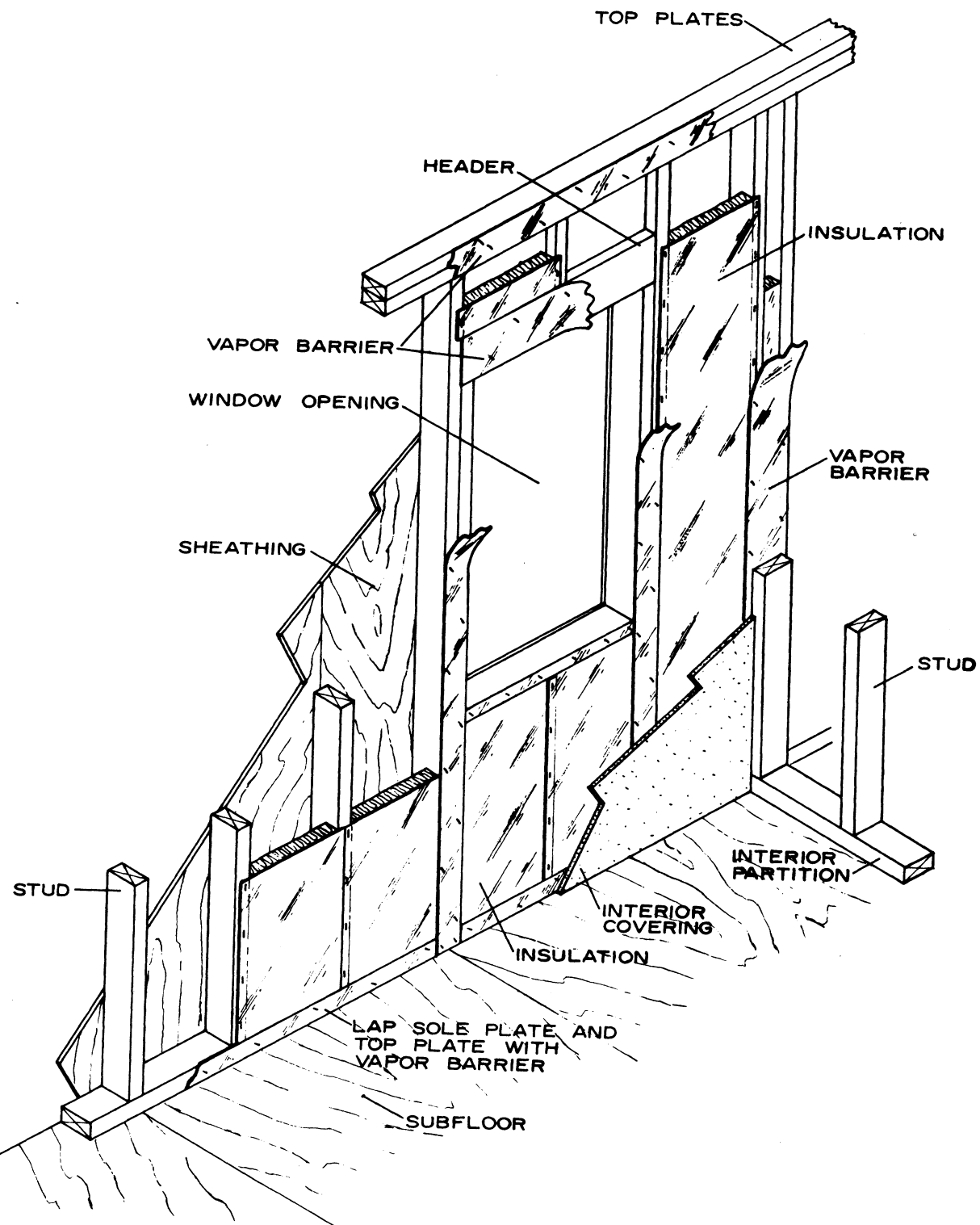


Figure 15.—Installing blanket insulation and vapor barriers in exterior wall.

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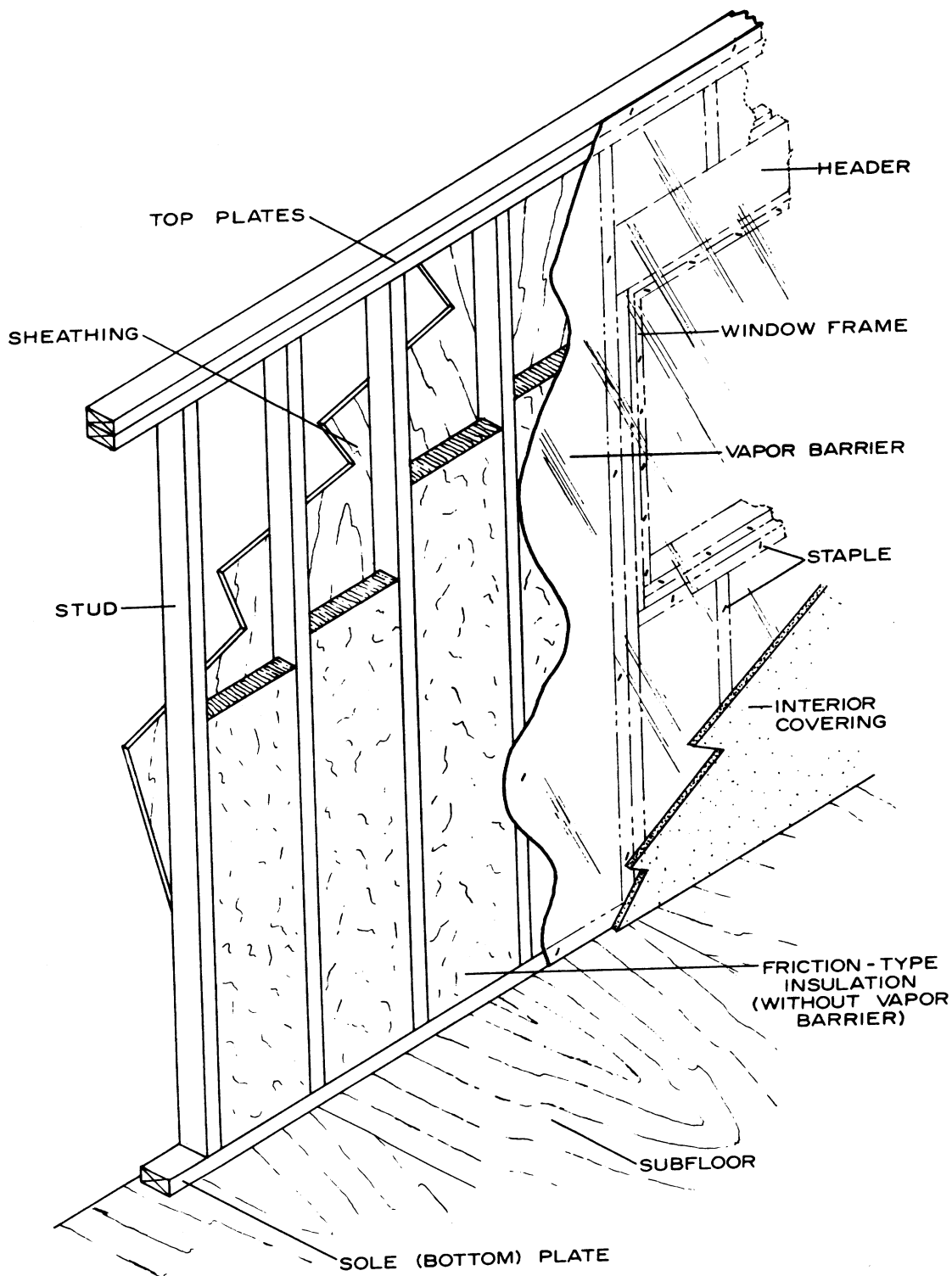


Figure 16.—Installing vapor barrier over friction-type insulation (enveloping).

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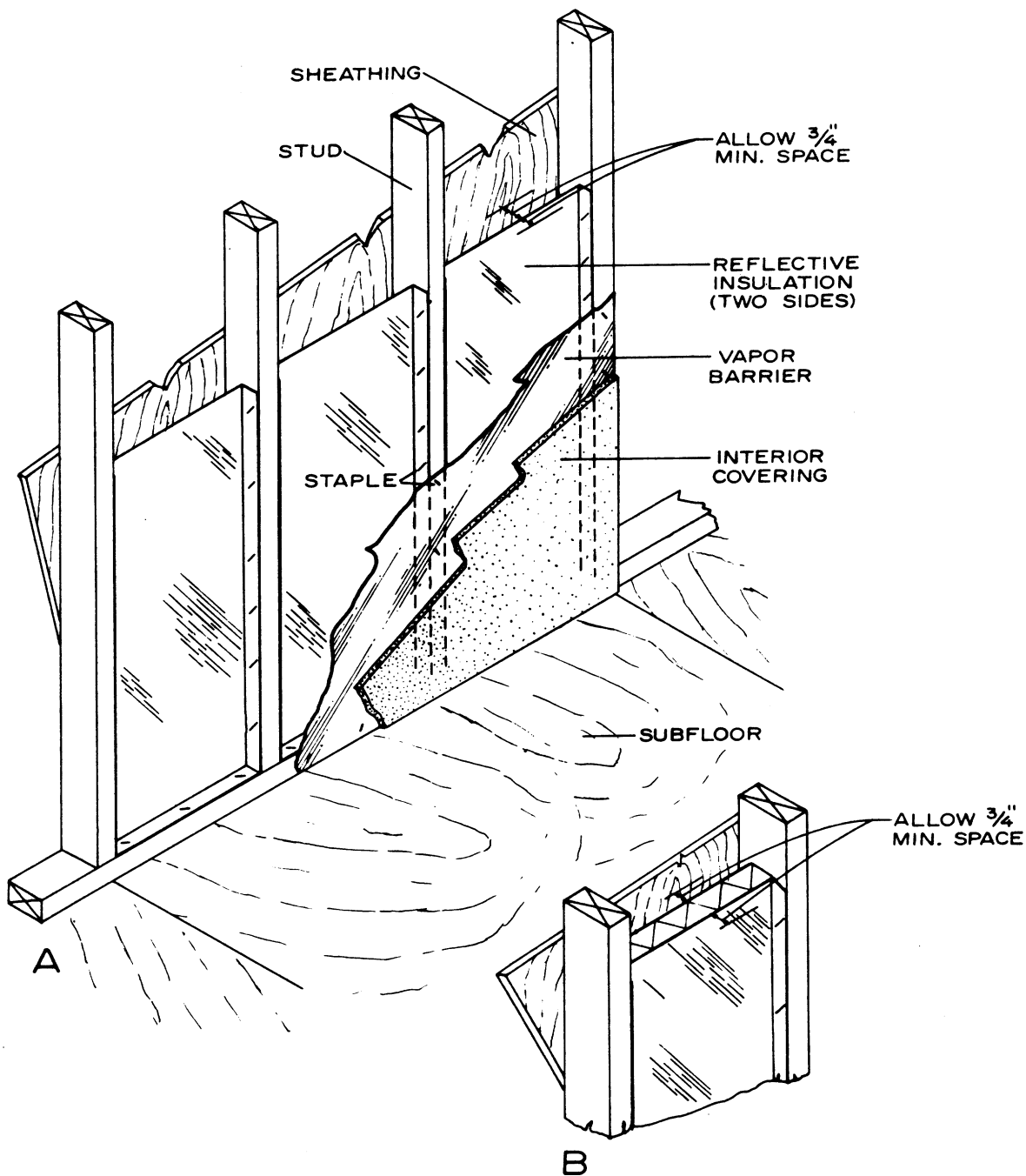


Figure 17.—Installing reflective insulation: A, Single sheet, reflective two sides; B, multiple reflective insulation.

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two-story house where the requirement of a vapor barrier and insulation is often overlooked is at the perimeter area of the second floor joists. The space between the joists at the header and along the stringer joists should be protected by sections of batt insulation which contain a vapor barrier (fig.

18). The sections should fit tightly so that both the vapor barriers and the insulation fill the joist spaces.

A two-story house is sometimes designed so that part of the second floor projects beyond the first. This projection varies but is often about 12 inches. In such designs, the

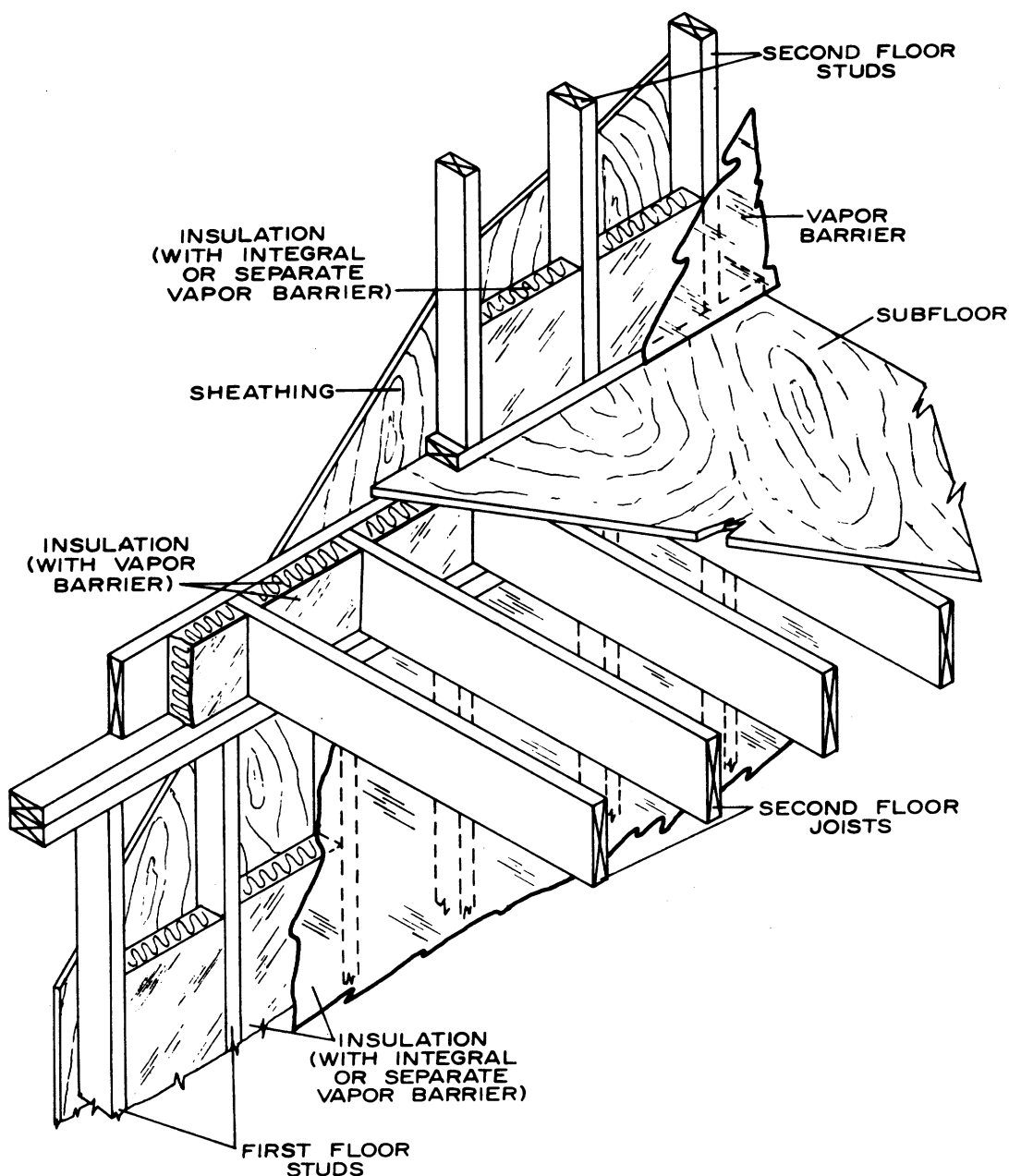


Figure 18.—Vapor barriers in walls and joist space of two-story house.

M 139 220

projections should be insulated and vapor barriers installed as shown in figure 19.

Insulation and vapor barriers in exposed second floor walls (fig. 18) should be installed in the same manner as for walls of single-story houses. This might include: (a) standard blanket insulation with its integral vapor barrier; (b) friction-type insulation with separate vapor barrier (fig. 16); or (c) reflective insulation with the protective vapor barrier

(fig. 17).

Knee walls.—In 1-1/2-story houses containing bedrooms and other occupied rooms on the second floor, it is common practice to include knee walls. These are partial walls which extend from the floor to the rafters (fig. 20). Their height usually varies between 4 and 6 feet. Such areas must normally contain vapor barriers and insulation in the following areas: (a) In the first floor ceiling area, (b) at the

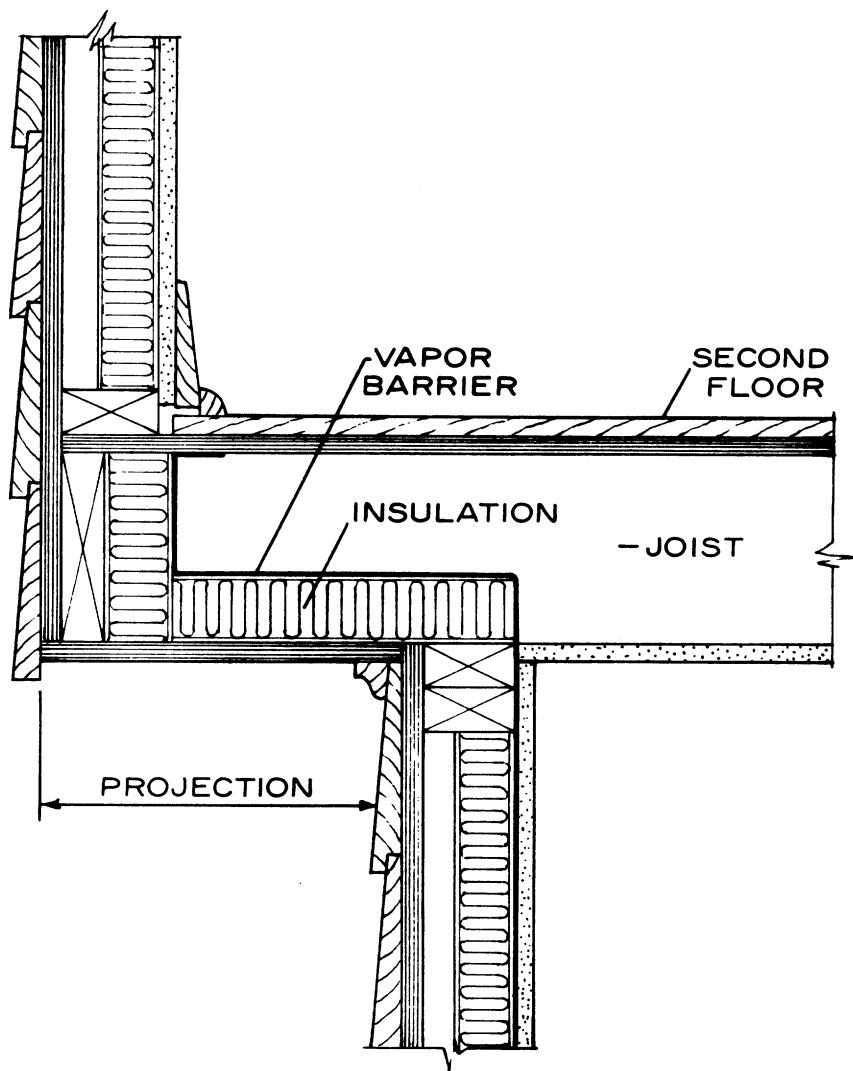


Figure 19.—Insulation and vapor barrier at second floor projection.

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knee wall, and (c) between the rafters. Insulation batts with the vapor barrier facing down should be placed between joists from the outside wall plate to the knee wall. The insulation should also fill the entire joist space directly under the knee wall (fig. 20). Care should be taken when placing the insulating batt to allow an airway for attic ventilation at the junction of the rafter and exterior wall.

Insulation in the knee wall can consist of blanket or batt-type insulation with integral vapor barrier or with separately applied vapor barriers, as described for first and second floor walls.

Batt or blanket insulation is commonly used between the rafters at the sloping portion of the heated room, figure 20. As in the applica-

tion of all insulations, the vapor barrier should face the inner or warm side of the roof or wall. An airway should always be allowed between the top of the insulation and the roof sheathing at each rafter space. This should be at least 1-inch clear space without obstructions such as might occur with solid blocking. This will allow movement of air in the area behind the knee wall to the attic area above the second floor rooms (fig. 6).

Ceilings and Attics

Vapor barriers and insulation.—Insulation in ceiling areas normally consists of the batt or fill-type. However, to provide for good condensation control, a vapor barrier should always be provided (fig. 21, A). When an insulation batt is supplied with a vapor barrier on one

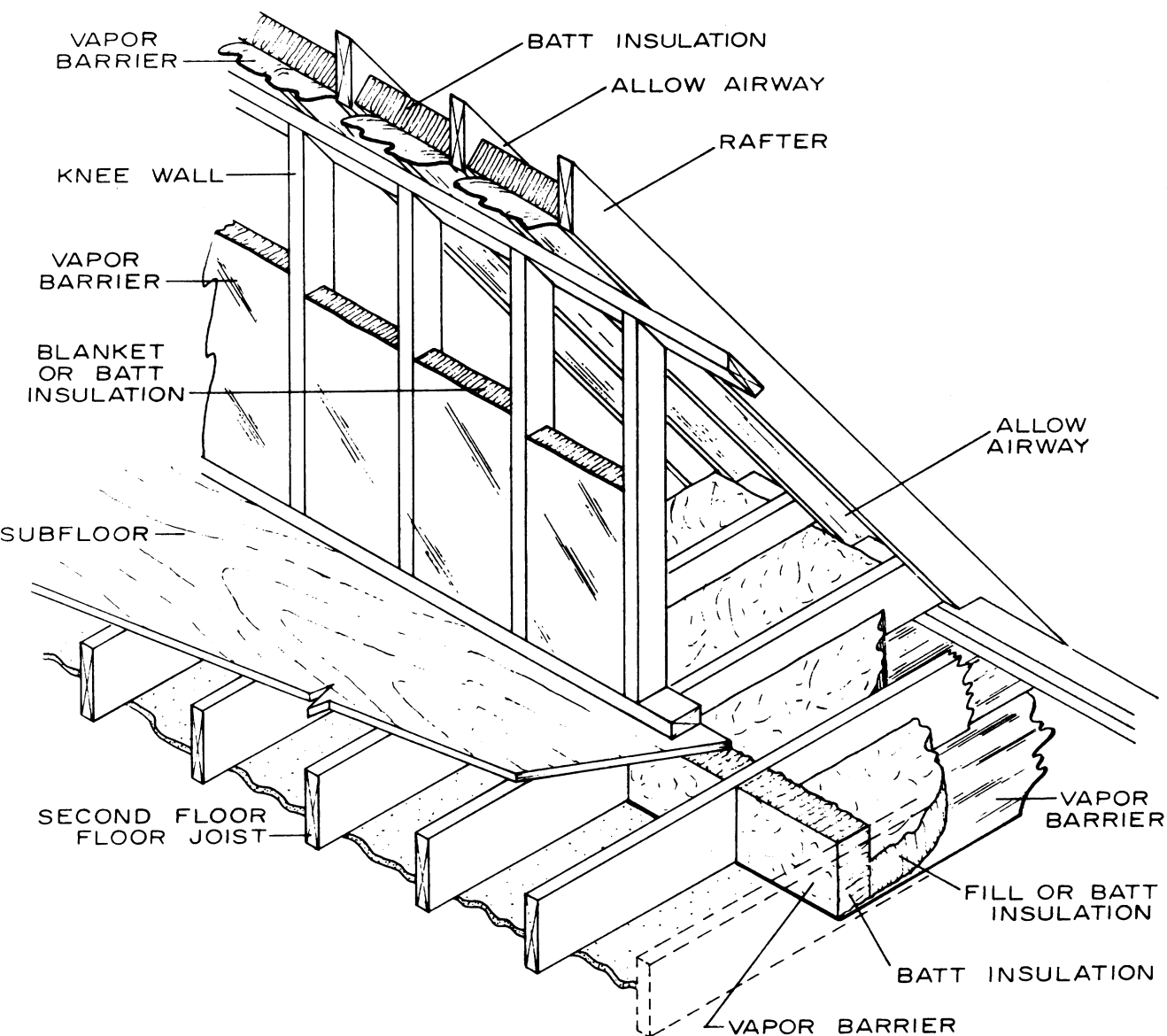


Figure 20.—Installing vapor barrier and insulation in knee-wall areas of 1-1/2-story house.

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face, no additional protection is normally required. Place the batts with barrier side down, so that they fit tightly between ceiling joists. Batts with the vapor barrier attached can also be stapled to the bottom edge of the joists before the ceiling finish is applied. At the junction of the outside walls and rafters, a space should always be left below the roof boards to provide a ventilating airway (fig. 21, B).

Ventilation.—Ventilation of attic spaces and roof areas is important in minimizing water vapor buildup. However, while good ventilation is important, there is still a need

for vapor barriers in ceiling areas. This is especially true of the flat or low-slope roof where only a 1- to 3-inch space above the insulation might be available for ventilation.

In houses with attic spaces, the use of both inlet and outlet ventilation is recommended. Placing inlet ventilators in soffit or frieze-board areas of the cornice and outlet ventilators as near the ridge-line as possible will assure air movement through a "stack" effect. This is due to the difference in height between inlet and outlet ventilators and normally assures air movement even on windless days or nights.

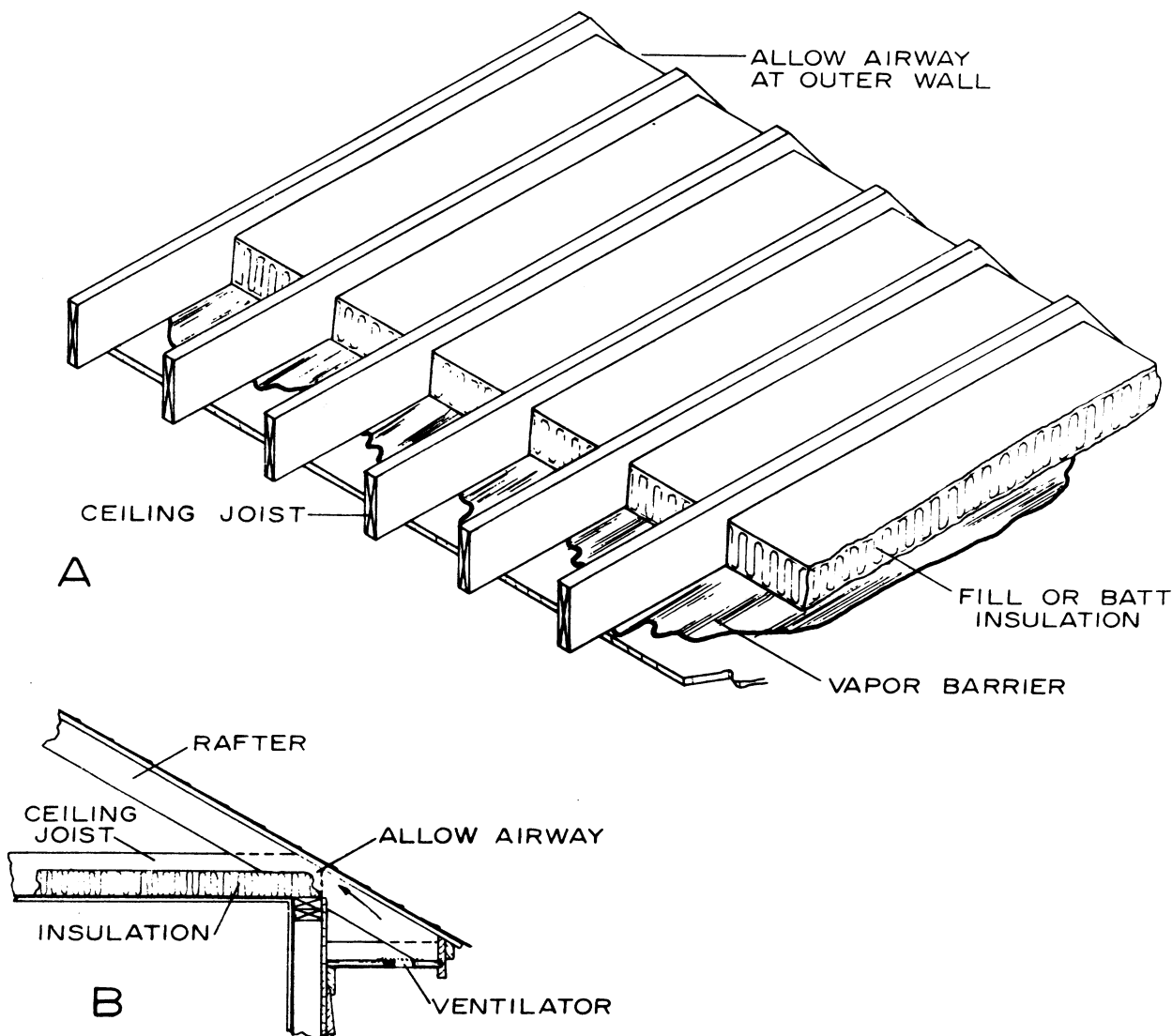


Figure 21.—Installing ceiling insulation and vapor barrier: A, Vapor barrier and insulation; and B, airway for ventilation.

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Recommended ventilating areas.—The minimum amount of attic or roof space ventilation required is determined by the total ceiling area. These ratios are shown in figures 22, 23, and 24 for various types of roofs. The use of both inlet and outlet ventilators is recommended whenever possible. The total net area of ventilators is found by application of the ratios shown in figures 22, 23, and 24. The total area of the ventilators can be found by using the data in table 2. Divide this total area by the number of ventilators used to find the recommended square-foot area of each.

For example, a gable roof similar to figure 22, B with inlet and outlet ventilators has a

minimum required total inlet and outlet ratio of $1/900$ of the ceiling area. If the ceiling area of the house is 1,350 square feet, each net inlet and outlet ventilating area should be 1,350 divided by 900 or $1\frac{1}{2}$ square feet.

If ventilators are protected with No. 16-mesh insect screen and plain metal louvers, table 2, the minimum gross area must be $2 \times 1\frac{1}{2}$ or 3 square feet. When one outlet ventilator is used at each gable end, each should have a gross area of $1\frac{1}{2}$ square feet (3 divided by 2). When distributing the soffit inlet ventilators to three on each side, for a small house (total of 6), each ventilator should have a gross area of 0.5 square feet. For long

END ELEVATIONS

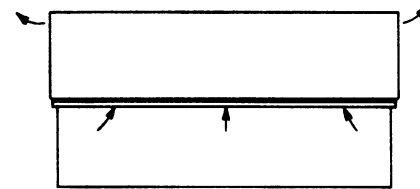
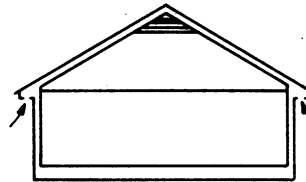
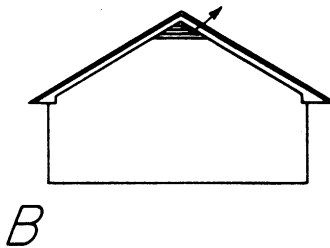
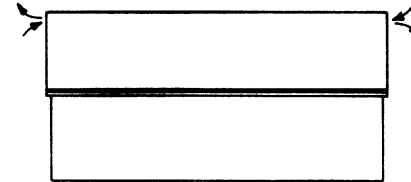
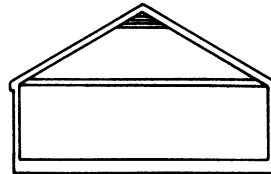
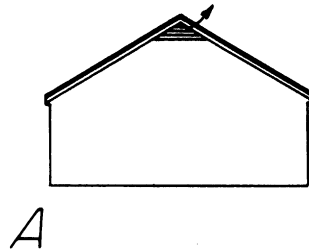
CROSS SECTIONS

SIDE ELEVATIONS

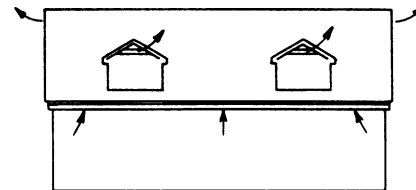
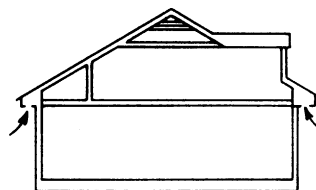
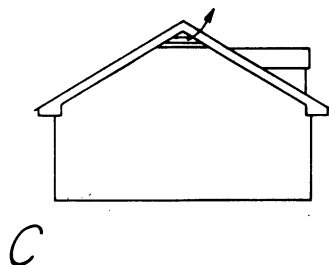
RATIO OF TOTAL
MINIMUM NET
VENTILATOR AREA
TO CEILING AREA

INLET OUTLET

0 $\frac{1}{300}$
(COMBINED)



$\frac{1}{900}$ $\frac{1}{900}$



$\frac{1}{900}$ $\frac{1}{900}$

Figure 22.—Ventilating areas of gable roofs: A, Louvers in end walls; B, louvers in end walls with additional openings at eaves; C, louvers at end walls with additional openings at eaves and dormers. Cross section of C shows free opening for air movement between roof boards and ceiling insulation of attic room.

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END ELEVATIONS

CROSS SECTIONS

SIDE ELEVATIONS

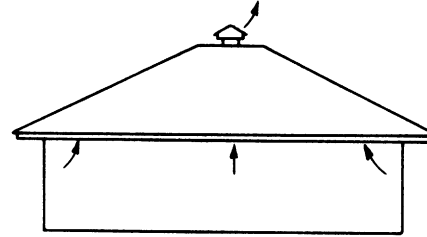
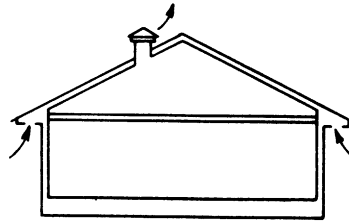
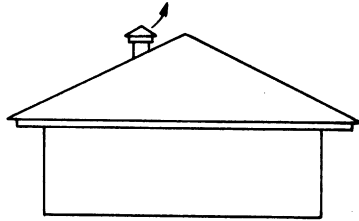
RATIO OF TOTAL
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TO CEILING AREA

INLET

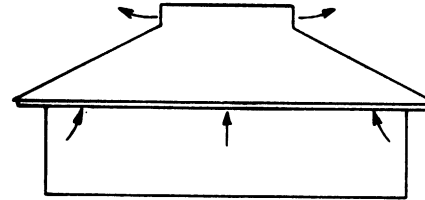
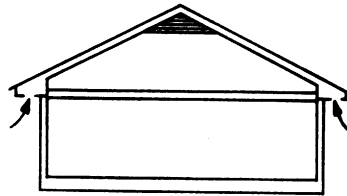
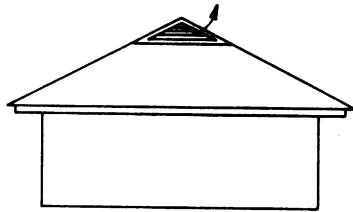
OUTLET

$\frac{1}{900}$

$\frac{1}{1,500}$



A



$\frac{1}{900}$

$\frac{1}{900}$

B

Figure 23.—Ventilating areas of hip roofs: A, inlet openings beneath eaves and outlet vent near peak; B, inlet openings beneath eaves and ridge outlets.

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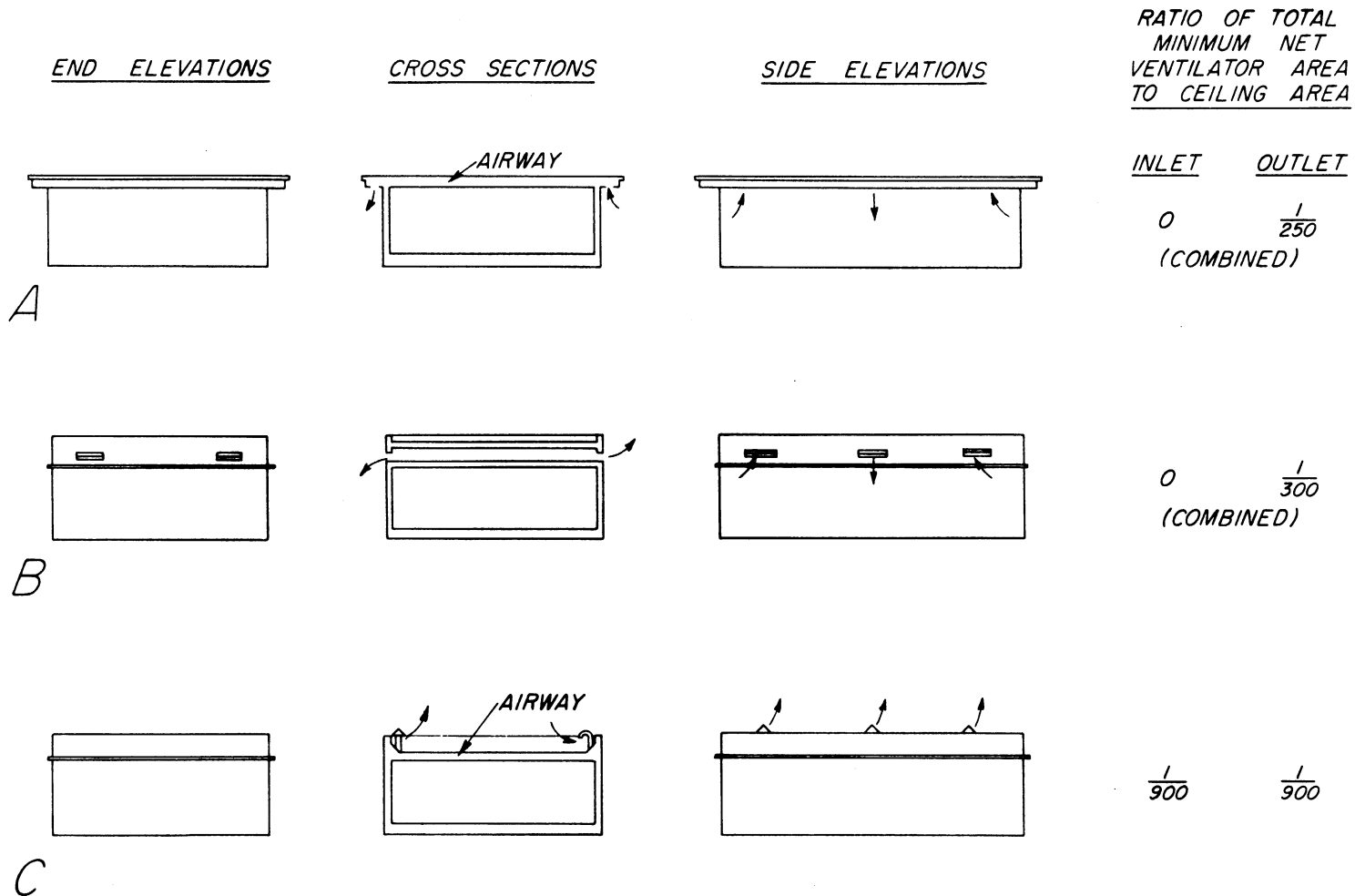


Figure 24.—Ventilating area of flat roofs: A, Ventilator openings under overhanging eaves where ceiling and roof joists are combined; B, for roof with a parapet where roof and ceiling joists are separate; C, for roof with a parapet where roof and ceiling joists are combined.

M 87627 F

houses, use 6 or more on each side.

Inlet ventilators.—Inlet ventilators in the soffit may consist of several designs. It is good practice to distribute them as much as possible to prevent “dead” air pockets in the attic where moisture might collect. A

continuous screened slot, figure 25, A, satisfies this requirement. Small screened openings might also be used, figure 25, B. Continuous slots or individual ventilators between roof members should be used for flat-roof houses where roof members serve as both rafters and

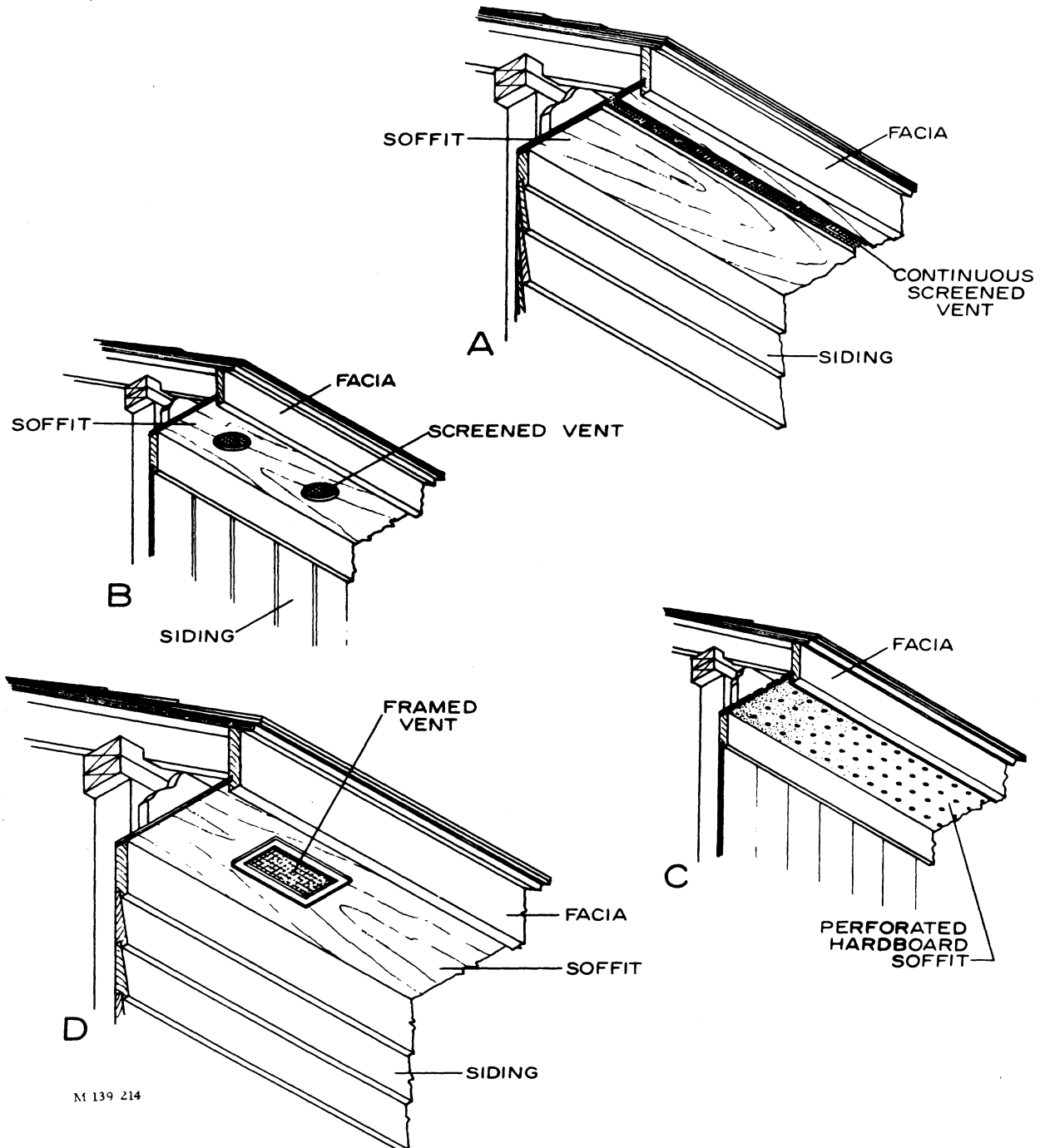


Figure 25.—Inlet ventilators in soffits: A, Continuous vent; B, round vents; C, perforated; D, single ventilator.

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ceiling joists. Locate the openings away from the wall line to minimize the possible entry of wind-driven snow. A soffit consisting of perforated hardboard, figure 25, C, can also be used to advantage but holes should be no larger than 1/8 inch in diameter. Small metal frames with screened openings are also available and may be used in soffit areas, figure 25, D. For open cornice design, the use of a frieze board with screen ventilating slots would be satisfactory, figure 26. Perforated hardboard might also be used for this purpose. The recommended minimum inlet ventilating ratios shown in figures 22, 23, and 24 should be followed in determining total net ventilating areas for both inlet and outlet ventilators.

Outlet ventilators.—Outlet ventilators to be most effective should be located as close to the highest portion of the ridge as possible. They may be placed in the upper wall section of a gable-roofed house in various forms as shown in figure 27, A and B. In wide gable-end overhangs with ladder framing, a number of screened openings can be located in the soffit area of the lookouts (fig. 27, C). Ventilating openings to the attic space should not be

restricted by blocking. Outlet ventilators on gable or hip roofs might also consist of some type of roof ventilator (fig. 28, A and B). Hip roofs can utilize a ventilating gable (modified hip) (fig. 28, C). Protection from blowing snow must be considered, which often restricts the use of a continuous ridge vent. Locate the single roof ventilators (fig. 28, A and B) along the ridge toward the rear of the house so they are not visible from the front. Outlet ventilators might also be located in a chimney as a false flue which has a screened opening to the attic area.

Other Protective Measures

Snow and ice dams.—Water leakage into walls and interiors of houses in the snow belt areas of the country is sometimes caused by ice dams and is often mistaken for condensation. Such problems occur after heavy snowfalls when there is sufficient heat loss from the living quarters to melt the snow along the roof surface. The water moves down the roof surface to the colder overhang of the roof where it freezes. This causes a ledge of ice and backs up water, which can enter the wall or drip down onto the ceiling finish (fig. 29, A).

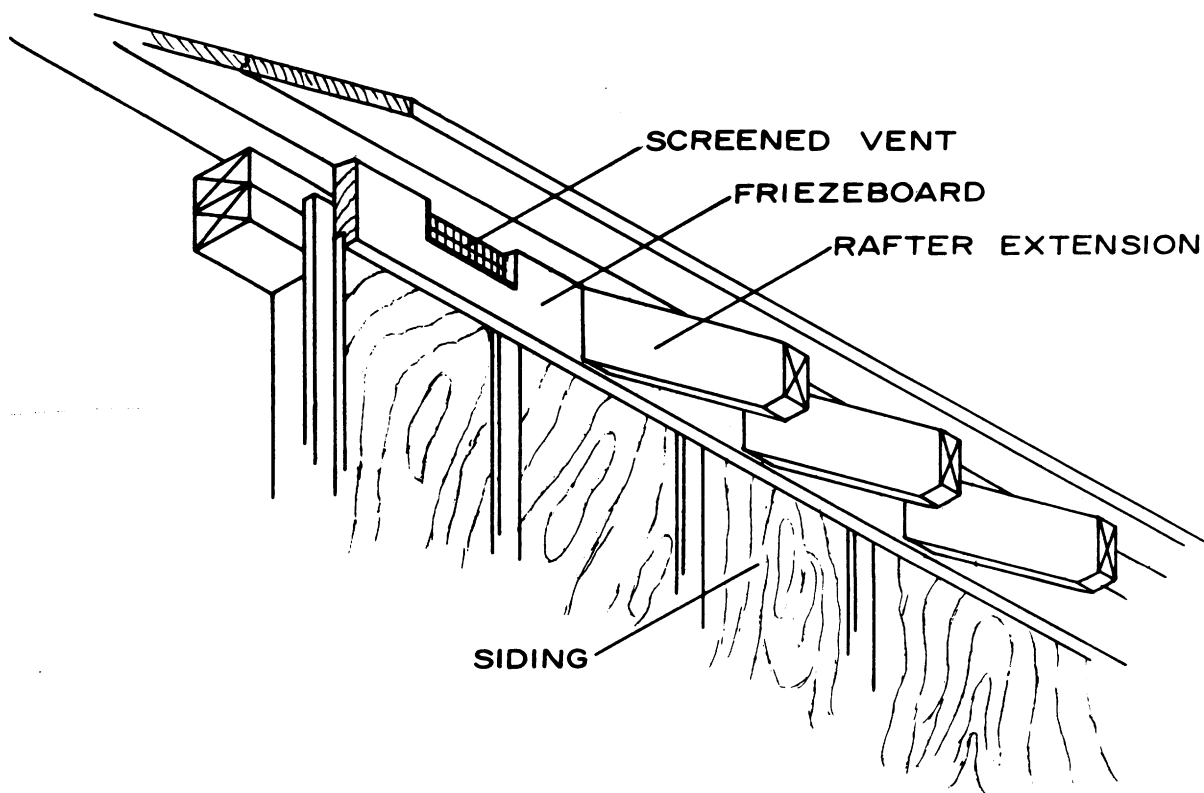


Figure 26.—Frieze ventilator (for open cornice).

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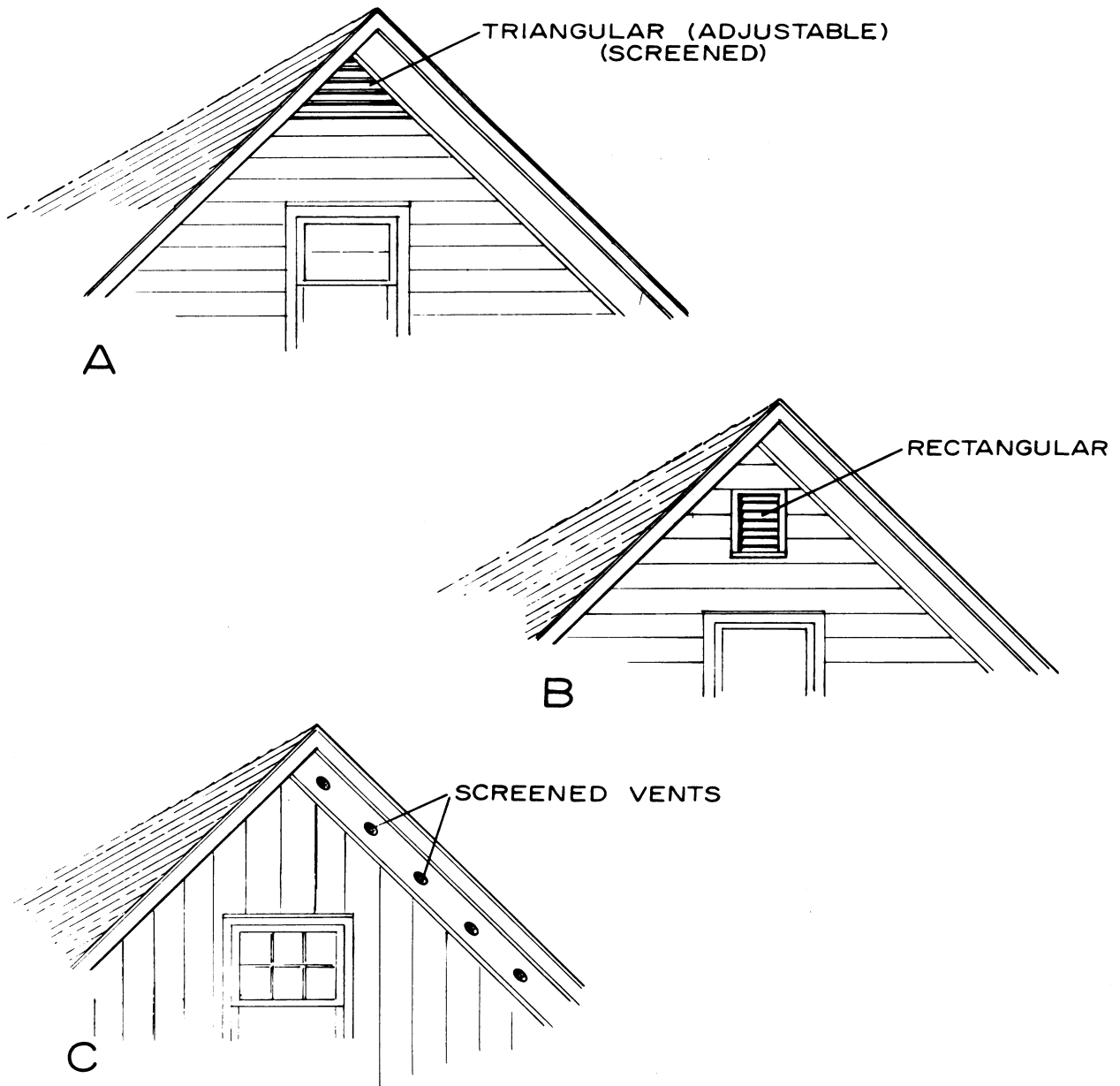


Figure 27.—Gable outlet ventilators: A, Triangular gable end ventilator; B, rectangular gable end ventilator; C soffit ventilators.

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Ice dam problems can be minimized if not entirely eliminated. By reducing attic temperatures by adequate insulation and ventilation, snow melting at the roof surface is greatly reduced. Good insulation, 6 inches or more in the northern sections of the country, greatly reduces heat loss from the house proper. Adequate ventilation, in turn, tends to keep attics dry with temperatures only slightly above outdoor temperatures. This combination of good ventilation and insulation is the answer

to reducing ice dam problems.

Another protective measure is provided by the use of a flashing material. A 36-inch width of 45-pound roll roofing along the eave line will provide such added protection (fig. 29, B).

Protection at unheated areas.—Walls and doors to unheated areas such as attic spaces should be treated to resist water vapor movement as well as to minimize heat loss. This includes the use of insulation and vapor barriers

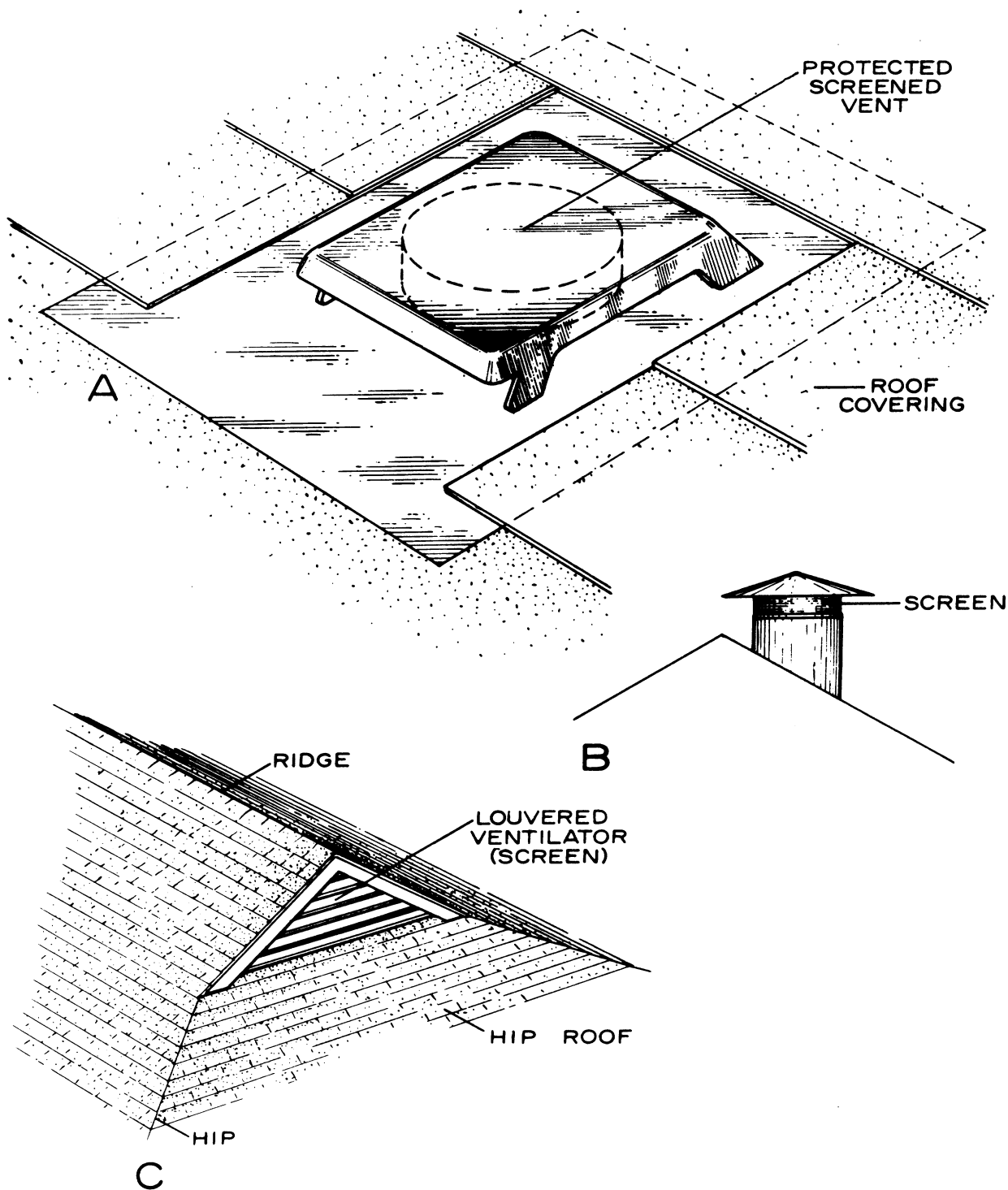
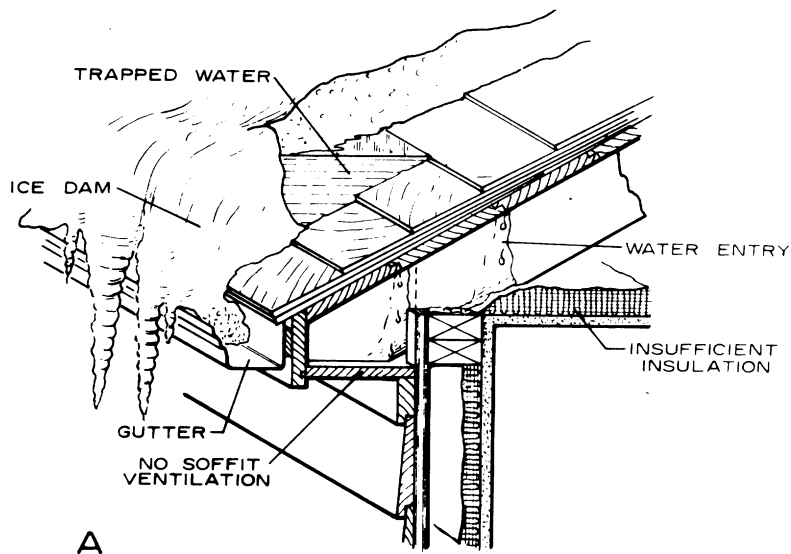
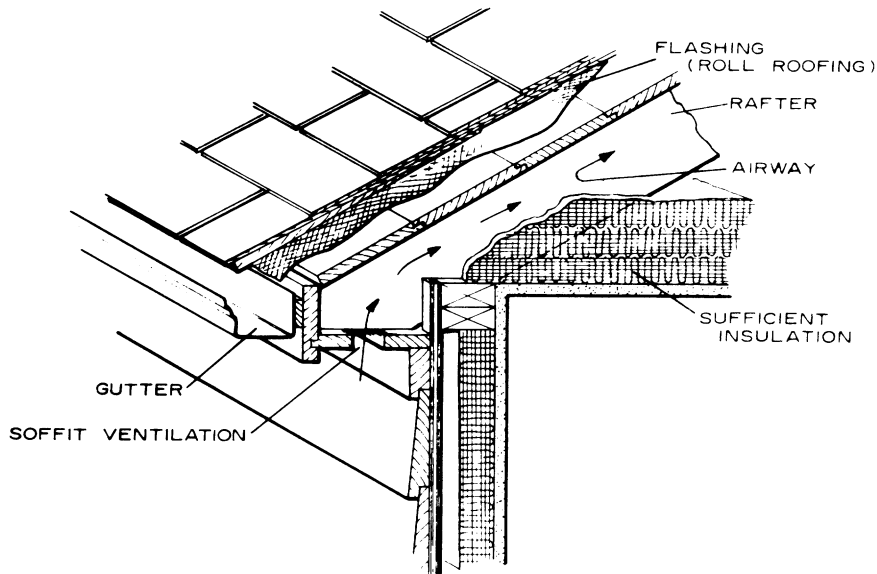


Figure 28.—Ridge outlet ventilators: A, Low silhouette type; B, pipe ventilator type; C, modified hip ventilator.

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A



B

Figure 29.—Ice dams: A, Insufficient insulation and ventilation can cause ice dams and water damage; B, good ventilation, insulation, and roof flashing minimize problems.

M 134 787

on all wall areas, adjacent to the cold attic (fig. 30). Vapor barriers should face the warm side of the room. In addition, some means should be used to prevent heat and vapor loss around the perimeter of the door. One method is through some type of weather strip (fig. 30). The door itself should be given

several finish coats of paint or varnish which will resist the movement of water vapor.

If further resistance to heat loss is desired, a covering of 1/2 inch or thicker rigid insulation, such as insulation board or foamed plastic, can be attached to the back of the door.

Protection at outlet boxes.—Outlet or

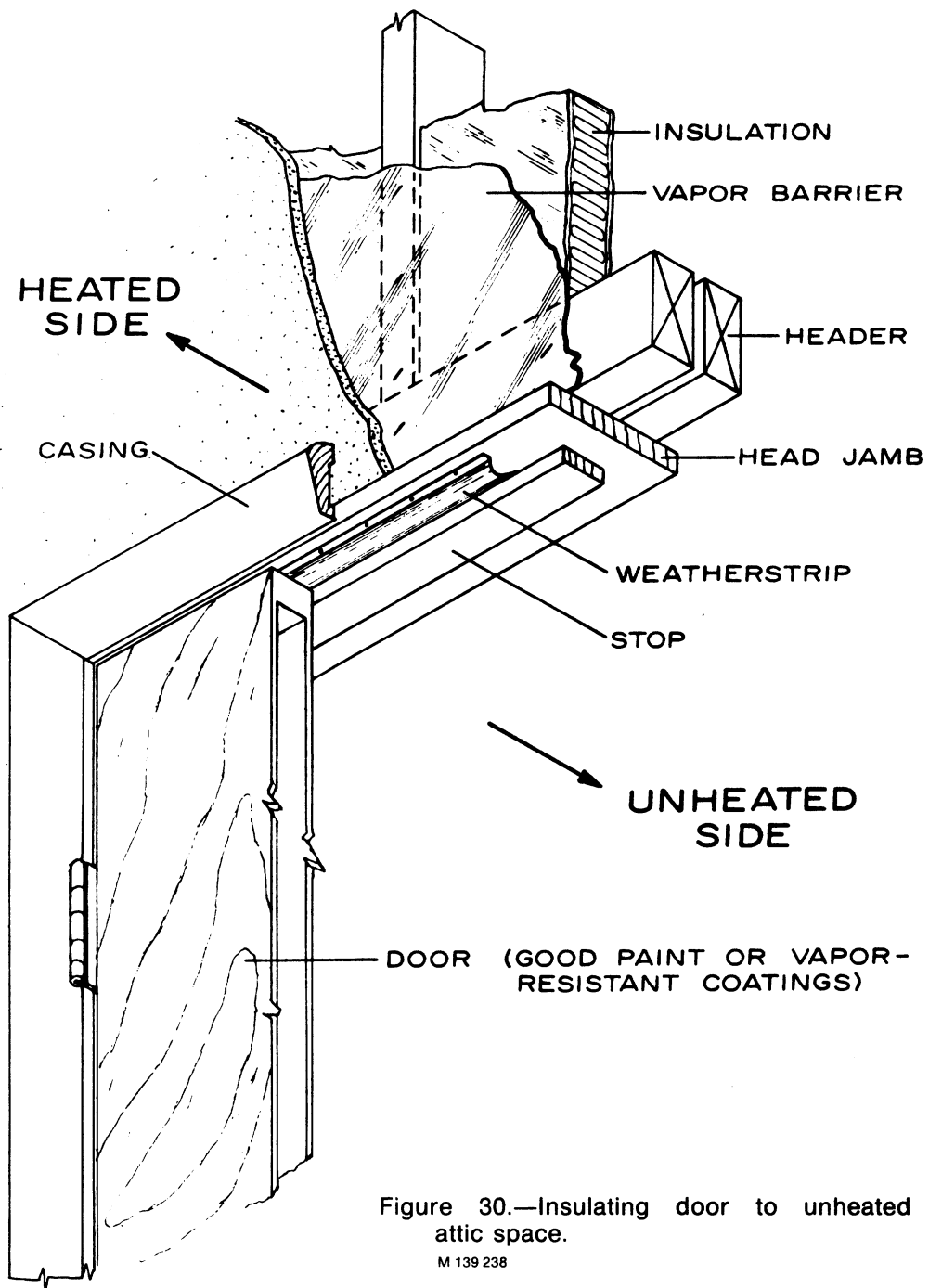


Figure 30.—Insulating door to unheated attic space.

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switch boxes or other openings in exposed (cold) walls often are difficult to treat to prevent water vapor escape. Initially, whether the vapor barrier is a separate sheet or part of the insulation, as tight a fit as possible should be made when trimming the barrier around the box (fig. 31). This is less difficult when the barrier is separate. As an additional precaution, a bead of calking compound should be applied around the box after the dry wall

or the plaster base has been installed (fig. 31). The same calking can be used around the cold-air return ducts or other openings in exterior walls. This type of sealing may appear unnecessary, but laboratory tests have shown that there is enough moisture loss through the perimeter of an outlet box to form a large ball of frost on the back face during extended cold periods. Melting of this frost can adversely affect the exterior paint films. In the colder

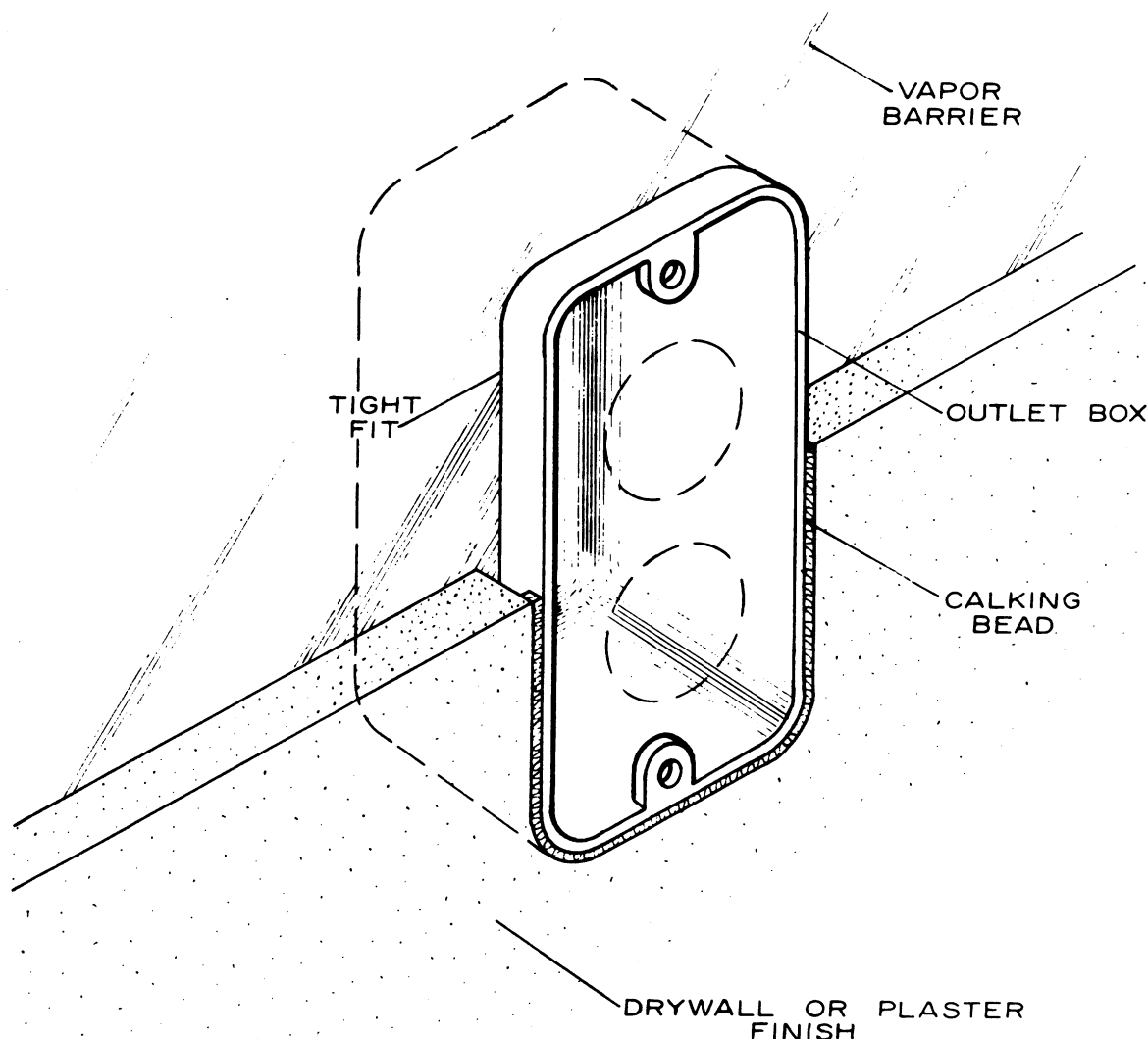


Figure 31.—Protection around outlet boxes in exposed walls.

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areas of the country and in rooms where there is excess water vapor, such as the bath and kitchen, this added protection is good insurance from future problems. Some switch and junction boxes are more difficult to seal than others because of their makeup. A simple polyethylene bag or other enclosure around such boxes will provide some protection.

Condensation problems caused by water-vapor movement through unprotected outlet box areas in exposed walls are often due to poor workmanship during application of the insulation. Figure 32 shows a section of exterior wall with the vapor barrier loosely stapled to the face of the studs. Because of poor application, a small space is sometimes left at the

top and bottom of the insulation in the stud space. Water vapor escaping through the unprotected outlet box travels by convection, on the warm side, to the top of the wall, where it moves to the cold side and condenses on the inner face of the colder siding or sheathing. Continued movement of vapor can saturate these materials and in severe conditions cause decay. Buckling of single panel siding, such as hardboard or similar materials, can result as moisture content of the material increases. Such problems can be minimized by “enveloping” of the inner face of exposed walls with a vapor barrier, as previously outlined (fig. 16). Sealing the outlet box in some manner will also aid in restricting water vapor movement into the

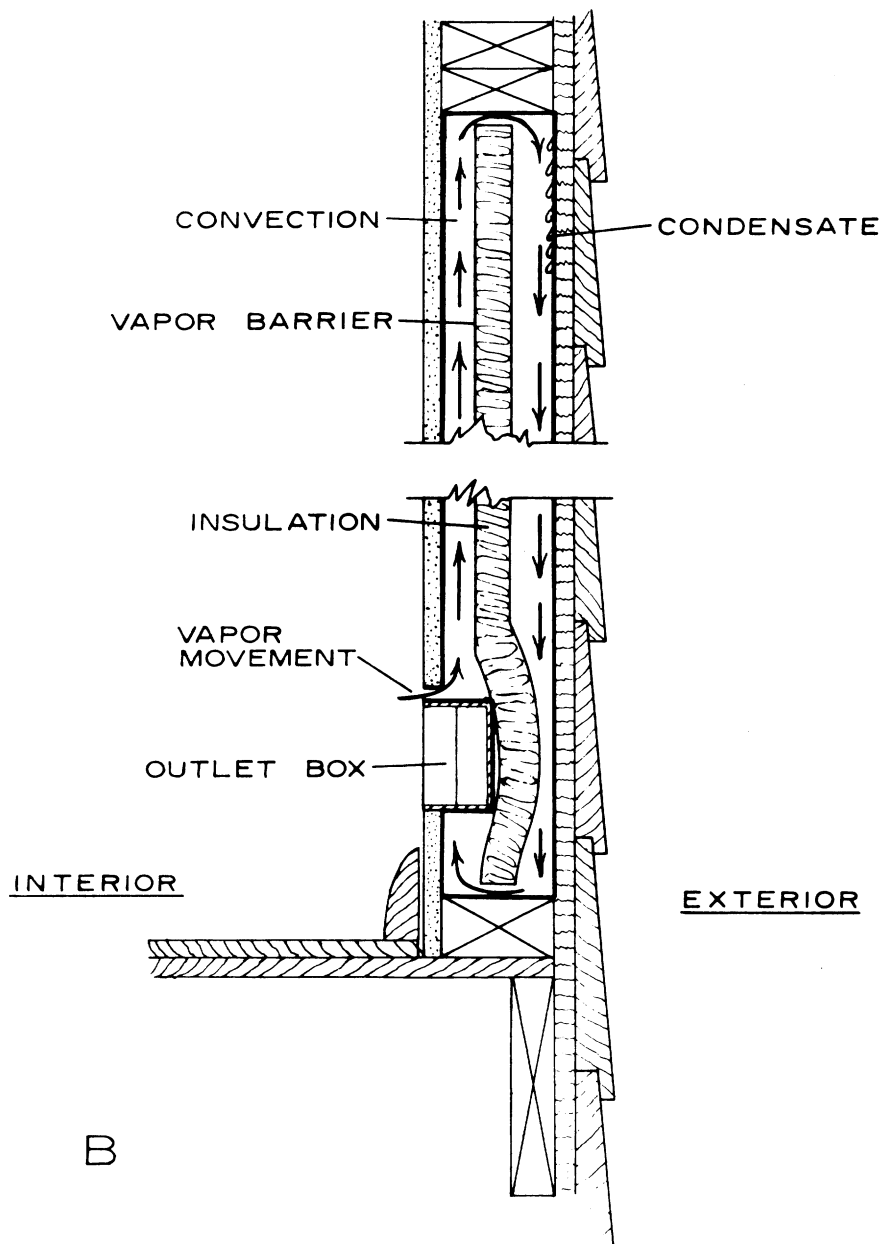


Figure 32.—Results of water vapor loss around outlet box.

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wall cavity.

Other openings.—The same principles used in sealing outlet boxes should be applied to all openings in an outside wall or ceiling. Openings may include exhaust fans in the kitchen or the bathroom, hot air registers,

cold air return registers, and plumbing. Openings are also required in ceilings for light fixtures, ventilation fans, and plumbing vents. Regardless of the type of opening, the vapor barrier should be trimmed to fit as tightly as possible.

HOW TO MINIMIZE EXISTING CONDENSATION PROBLEMS

Condensation problems can be eliminated by specifying proper construction details during planning of the house. Correct placement of vapor barriers, adequate insulation, the use of attic ventilation, and other good practices can be incorporated at this time. These recommendations have been outlined and illustrated in the preceding sections. However, when one or more of these details have not been included in an existing house and condensation problems occur, they are often more difficult to solve. Nevertheless, there are methods which can be used to minimize such condensation problems after the house has been constructed.

Visible Condensation

Glass surfaces.—Visible surface condensation on the interior glass surfaces of windows can be minimized by the use of storm windows or by replacing single glass with insulated glass. However, when this does not prevent condensation on the surface, the relative humidity in the room must be reduced. Drapes or curtains across the windows hinder rather than help. Not only do they increase surface condensation because of colder glass surfaces, but they also prevent the air movement that would warm the glass surface and aid in dispersing some of the moisture.

Attic areas.—Condensation or frost on protruding nails, on the surfaces of roof boards, or other members in attic areas normally indicates the escape of excessive amounts of water vapor from the heated rooms below. If a vapor barrier is not already present, place one between joists **under** the insulation. Make sure the vapor barrier fits tightly around ceiling lights and exhaust fans, calking if necessary. In addition, increase both inlet and outlet ventilators to conform to the minimum recommendations in table 2. Decreasing the amount of water vapor produced in the living areas is also helpful.

Crawl spaces.—Surface condensation in unheated crawl spaces is usually caused by excessive moisture from the soil or from warm humid air entering from outside the house. To eliminate this problem, place a vapor barrier over the soil as shown in figure 10; if necessary, use the proper amount of ventilation as recommended in table 1.

Concrete slabs.—Concrete slabs without radiant heat are sometimes subjected to surface condensation in late spring when warm humid air enters the house. Because the

temperature of some areas of the concrete slab or its covering is below the dewpoint, surface condensation can occur. Keeping the windows closed during the day, using a dehumidifier, and raising the inside temperature aid in minimizing this problem. When the concrete slab reaches normal room temperatures, this inconvenience is eliminated.

Reducing Relative Humidity

Reducing high relative humidities within the house to permissible levels is often necessary to minimize condensation problems. Discontinuing the use of room-size humidifiers or reducing the output of automatic humidifiers until conditions are improved is helpful. The use of exhaust fans and dehumidifiers can also be of value in eliminating high relative humidities within the house. When possible, decreasing the activities which produce excessive moisture, as discussed in a previous section, is sometimes necessary. This is especially important for homes with electric heat.

Concealed Condensation

Concealed condensation is, in essence, a surface or similar condensation that takes place within a component such as a wall cavity when a condensing surface is below the dewpoint. In cold weather, condensation often forms as frost. Such conditions can cause staining of siding and peeling of the paint and possibly decay in severe and sustained conditions. These problems are usually not detected until spring after the heating season has ended. The remedies and solutions to the problems should be taken care of before repainting or residing is attempted. Several methods might be used to correct this problem.

(1) Reduce or control the relative humidity within the house as previously discussed.

(2) Add a vapor-resistant paint coating such as aluminum paint to the interior of walls and ceilings.

(3) Improve the vapor resistance of ceiling by adding a vapor barrier between ceiling joists.

(4) Improve attic ventilation (figs. 22, 23, and 24).

Ice dam

Several methods can be used to minimize this problem caused by melting snow. By reducing the attic temperatures in the winter so that they are only slightly above outdoor temperatures, most ice dams can be eliminated. This can be accomplished in the following manner:

(1) Add insulation to the ceiling area in

the attic to reduce heat loss from living areas below. This added insulation and ventilation will also be helpful by reducing summer temperatures in the living areas below.

(2) Provide additional inlet ventilation in the soffit area of the cornice as well as better outlet ventilation near the ridge.

(3) When reroofing, use a flashing strip of 36-inch-wide roll roofing paper of 45-pound weight along the eave line before reshingling.

While this does not prevent ice dams, it is a worthwhile precaution.

(4) Under severe conditions, or when only some portions of a roof produce ice dams (such as at valleys), the use of electric-thermal wire laid in a zig-zag pattern and in gutters may prove effective. The wire is connected and heated during periods of snowfall and at other times as needed to maintain channels for drainage.

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GLOSSARY OF SOME CONDENSATION AND HOUSING TERMS

Condensation.—Formation of water on cold surfaces below the dew point temperature of the surrounding air. It may occur on the surface of a window glass, for example (surface condensation), or on a cold inner face of wall sheathing (concealed condensation), or within a material. Excessive condensation especially in the walls, can cause problems which often result in excessive maintenance and increases in heating costs.

Crawl space.—A shallow space below the living quarters of a house. It is generally not excavated and may be constructed with a foundation wall or with piers and a skirt board enclosure.

Dew Point.—The temperature at which the water vapor in space becomes saturated and can hold no more moisture. Water vapor cooled below the dew point appears in the atmosphere as fog and on the surface as water or frost.

Humidifier.—A device designed to discharge water vapor into a confined space for the purpose of increasing or maintaining the relative humidity. It may be attached to the central heating plant or consist of small room-size units.

Ice dam.—Ice forming at the eave line from melting snow on the roof which pockets water that can enter walls and cornice.

Insulation.—Normally a low-density material used to reduce heat loss. It is made of wood fiber, cotton fiber, mineral or glass wool or fiber, vermiculite, expanded plastics, and others. It is made in several forms including:

- (a) **Flexible.**—in blanket or batt form.
- (b) **Fill.**—A loose form which can be poured or blown.
- (c) **Rigid.**—Includes insulating board or other materials in sheet or block form. Often used as sheathing materials, as perimeter insulation, etc.
- (d) **Reflective.**—A polished surface such as aluminum foil which has high reflectivity and low emissivity.

k (see Thermal conductivity)

Perm.—A measure of vapor movement through a material, i.e. grains per square foot

per hour per inch of mercury difference in vapor pressure at standard test conditions.

Permeance.—Rate of water vapor transmission through a material, measured in perms. Thus, the lower the permeance, the better the vapor barrier.

Relative humidity.—The amount of water vapor expressed as a percentage of the maximum quantity that could be present in the atmosphere at a given temperature. (The actual amount of water vapor that can be held in space increases with the temperature.)

Roll roofing.—Roofing material composed of fiber saturated with asphalt and supplied in 36-inch-wide rolls which cover 100 square feet including a lap seam. It can be obtained in weights of 45 to 90 pounds per roll.

Sheathing paper.—A paper for use between wood board sheathing and the exterior covering to reduce air infiltration. Materials such as 15-pound asphalt felt or red rosin paper with a perm value of 5 or greater is commonly used.

Thermal conductivity (k).—The amount of heat expressed in British thermal units (B.T.U.) that will pass through 1 square foot of uniform material, 1 inch thick, in 1 hour when the temperature difference between surfaces of the material is 1° F. The lower this value the better the material is for insulating purposes.

Vapor barrier.—A film, duplex paper, aluminum foil, paint coating or other materials which restrict the movement of water vapor from an area of high vapor pressure to one of lower pressure. Material with a perm value of 1.0 or less is normally considered a vapor barrier.

Vapor permeability.—The property of a material that allows the passage of water vapor.

Vapor, water.—Water vapor is an invisible gas present in varying amounts in the atmosphere. There is a maximum amount that can be held at a given temperature.

Ventilation.—The replacement, by outside air, of the air within the building.

